SINGAPORE POLYTECHNIC ET 0050

2018/2019 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 7 pages of Extracts from CP5 Tables making a total of 11 pages.

SECTION A : [10 Marks Each]

1(a) A industrial building needs **1750kW** (not kVA) at **power factor of 0.85** lagging. State the voltage, phases, number of wires and frequency that Singapore Power Services Limited will likely provide. What type of earthing system must be used? What is the maximum current that can be drawn from the given supply voltage at 1750kW? (6 marks)

1(b) Draw the diagram of a single-phase electrical installation adopting the TT earthing system, clearly labelled all the parts. (4 marks)

2 Temporary Electrical Installations for Construction and building sites requires the use of Socket Outlet Assembly (SOA).

(a) State four other areas where SOA is also applicable.
(b) State the requirements relating to the enclosure of the assembly and type of protective devices used for the SOA.
(c) State the colours used for 230 volts and 110 volts industrial plugs and sockets.
(d) State the minimum Inspection frequency required for Construction sites.

(10 marks)

3 Find a suitable conduit size for the installation of the following circuits: (Using the cable factor method.)

3 No. of single phase circuits consist of 1.5 mm^2 single-core PVC insulated cable for the phase conductor and the protective conductor.

1 No. of three 4-wire phase circuits consist of 2.5 mm^2 single-core PVC insulated cables with 1.5 mm^2 single core PVC insulated cables for the protective conductor.

The conduit run is 6.7m with one 90^o bend. (10 marks)

4(a) In a quiet area, the flat owner leaves his flat at 1.00pm and only returns at 1.00am, he decided to use a timer control circuit to gives the illusion of persons in the flat by switching on the light at 6.00pm and off at 11.00 pm. Help the owner to design such a control circuit where pressing the start button will cause the light to turn on after 6 hours and the light will turn off by itself after a further four hours. The stop button will reset the circuit. (6 marks)

4(b) Draw the lighting control circuit of switching two lamps simultaneous from three locations, label all components of the circuit. (4 marks)

5 An electrical distribution board has a single-line diagram as shown in Figure Q4(a). Determine the tripping times obtain from the Time/Current curve of the protective devices and state whether discrimination is achieved.

(a) When an overload current of 80A flowing in Load1 (4 marks)
(b) When a fault current of 155A occurs at Point A (4 marks)
(c) Which mechanism operates to clear the fault current in (i) (2 marks)

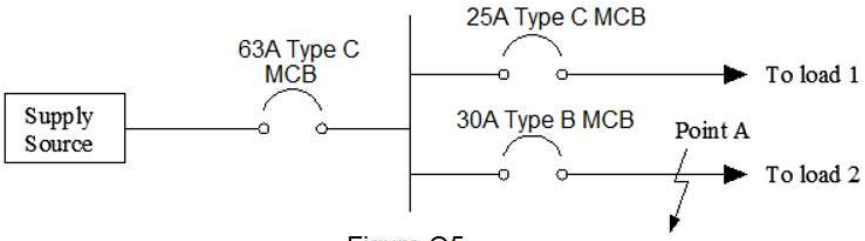

Figure Q5

6(a) An electrical installation with many circuits was divided into four sections for the Insulation Resistance Test. The values obtained are 16 MΩ, 16 MΩ, 8 MΩ and 4 MΩ. What is the equivalent insulation resistance value for the installation, and is it acceptable? (3 marks)

6(b) Give an example of Electrical Separation in the context of electrical installation. State the main equipment used in Electrical Separation and what is being separated. (3 marks)

6(c) In the earth electrode test done as per circuit shown in Figure Q6(c), the ammeter shows 5000mA, the voltmeter shows 10V, calculate the earth electrode resistance. Name any two types of earth electrodes that are acceptable for use in Singapore. (4 marks)

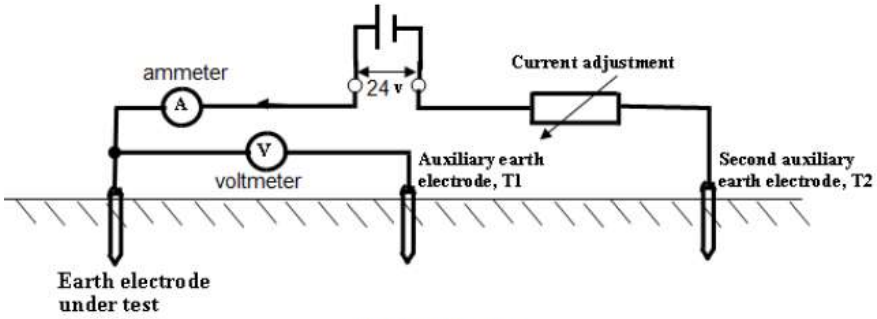

Figure Q6(c)

SECTION B : [20 Marks Each]

B1 A two-storey detached residential unit is taking supply from a three-phase 400V/230V 50 Hz supply. It has the following electrical loads:

- 10 nos. 2 x 32W fluorescent lamps
- 45 nos. 13A switched socket outlet connected in **3 ring circuits**, each protected by a 32A MCB (Estimated demand of each circuit is 3.5kW)
- 2 nos. instantaneous water heaters, each rated 3 kW
- 1 no. storage water heater rated 1.5kW
- 7.8kW cooker connected to cooker control unit with switched socket outlet
- 1500W audio video system connected to a 13A switched socket outlet
- Multi-split air-conditioning unit where the electrical load is to be considered as a three-phase motor, rated 8 kW with an efficiency of 88% and a power factor of 0.88.

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: 20A, 25A, 30A, 40A, 50A, 63A, 80A, 100A).

(19 marks)

B2(a) An electrical distribution board has a power requirement of 30kW at power factor of 0.88. The length of the cable is 70m from the main switchboard. It is to be wired in multi-core PVC insulated copper cables sharing a trunking with one other similar circuit. The ambient temperature can rise to 30^0 C. Determine:

(i) The design current of the electrical distribution board, hence the nominal rating of the Type C MCB.
(Standard circuit breaker rating: 15A, 20A, 25A, 30A, 32A, 40A, 50A, 63A)

(ii) A suitable cross section area of the cable

(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, cooker control unit 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 12 meters long. The value of Z_E is given as 0.75 Ω. Determine if the given size of the circuit protective conductor meets both the shock protection and thermal constraint requirements. (Given K=115)

(9 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 factors (Cg) Number of circuits or multicore cables											
		2	3	4	5	6	7	8	9	10	12	14	16
Enclosed (Method 3 or 4) or bunched 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
Single layer clipped to a non-metallic surface (Method 1)	Touching	0.85	0.79	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
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)

(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	$23/I_n$

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

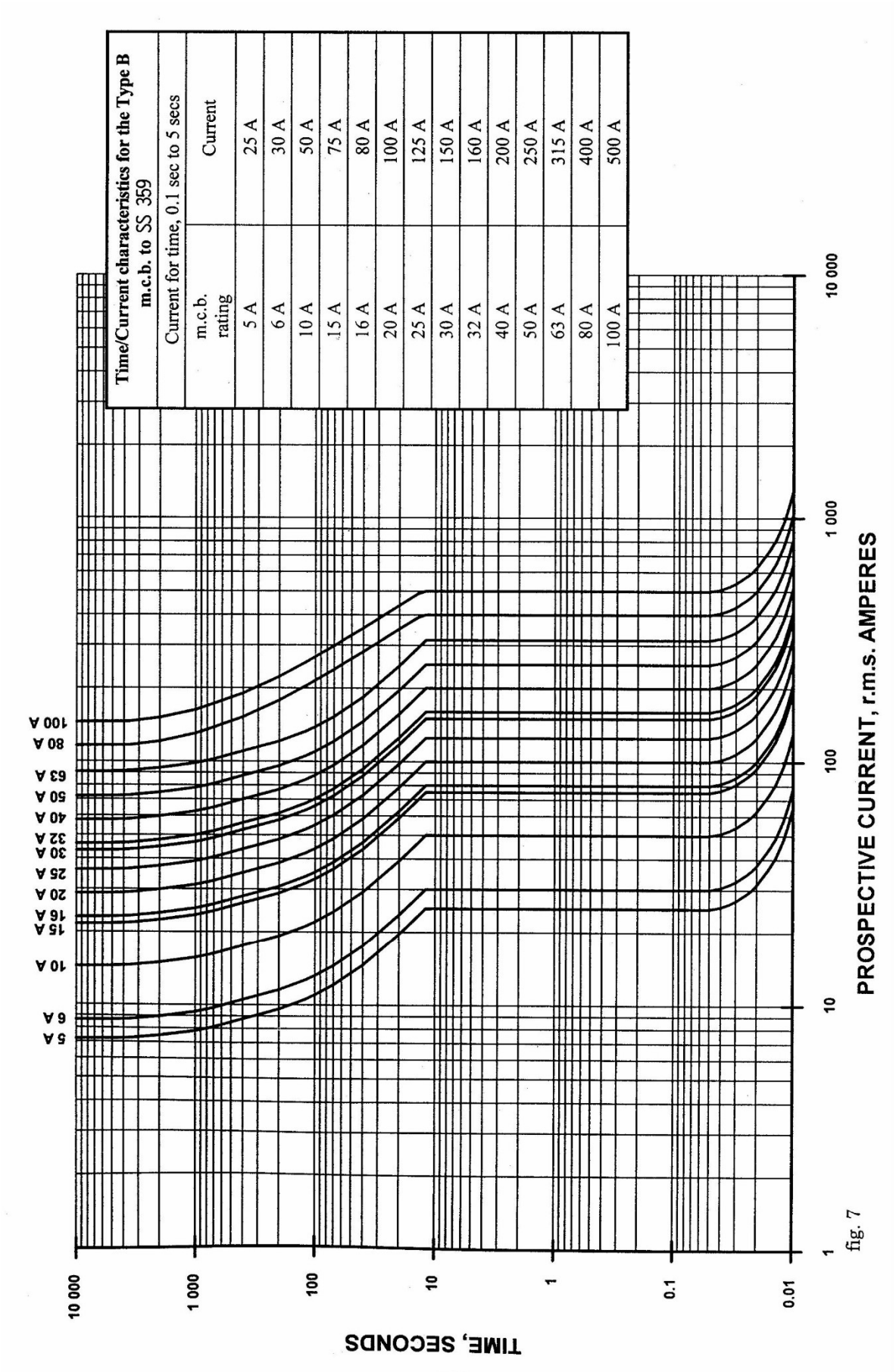
Time/Current characteristics for the Type B m.c.b. to SS 359
Current for time, 0.1 sec to 5 secs
m.c.b. rating
Current
5 A
25 A
6 A
30 A
10 A
50 A
15 A
75 A
16 A
80 A
20 A
100 A
25 A
125 A
30 A
150 A
32 A
160 A
40 A
200 A
50 A
250 A
63 A
315 A
80 A
400 A
100 A
500 A
TIME, SECONDS
10 000
1 000
100
10
1
0.1
0.01
PROSPECTIVE CURRENT, r.m.s. AMPERES
10 000
1 000
100
10
1
5 A
6 A
10 A
15 A
16 A
20 A
25 A
30 A
32 A
40 A
50 A
63 A
80 A
100 A

fig. 7

196

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.