SINGAPORE POLYTECHNIC ET0050

2019/2020 SEMESTER TWO EXAMINATION

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

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/SS638 Tables making a total of 11 pages.

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SECTION A : [10 Marks Each]

1(a) A shopping complex comprising of two buildings needs **3000kVA** 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 and power that can be drawn from the given supply voltage at 3000kVA? (6 marks)

1(b) A computer laboratory in a university uses electrical separation to prevent electrical shock to the students using the 13A switched socket outlets supplied by mains (230V 50Hz). Briefly explain how it is implemented. (4 marks)

2 State the requirements relating to the enclosure of the assembly and type of protective devices used for the SOA, also state the colours used for 110 volts, 230 volts and 400 volts industrial plugs and sockets. State the maximum number of 16A 2-pole and earth socket outlets that can be fed from a 32A, single phase, 230V source for a Socket Outlet Assembly complying with SS650 Part 1. (10 marks)

3(a) In the open ring diagram in Figure Q3(a) below, a ring circuit is shown where the resistance of the open ring is measured to be 0.04 ohms. Determine the resistance of the Closed ring to mid point value. (You may ignore the resistance of the meter leads.) (5 marks)

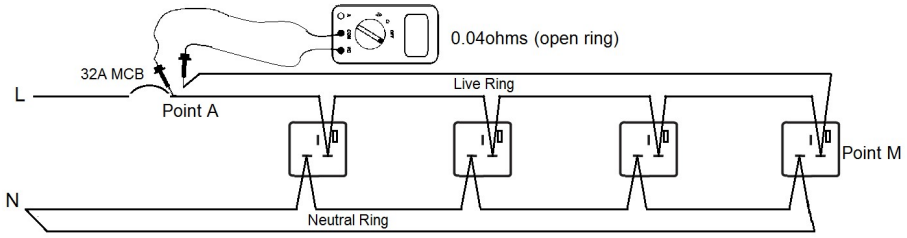

Figure Q3(a)(i) Open Ring

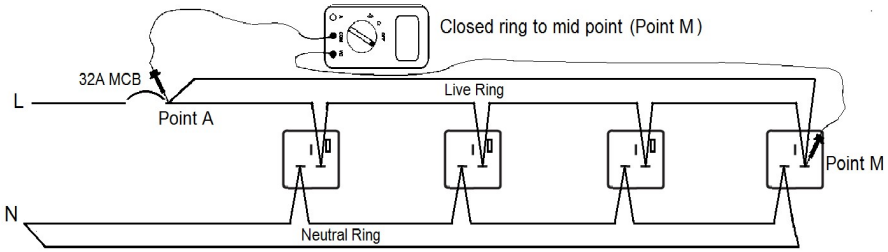

Figure Q3(a)(ii) Closed ring to mid point

3(b) Briefly explain the measures used in the fault protection (indirect contact) of Class II equipment. An apprentice in a worksite found that an electric drill (Class II equipment) has no earth and promptly proceed to add an earth wire to earth the electric drill, comment on the apprentice action. (5 marks)

4(a) Design and draw a control circuit with the following requirements:

Upon pressing the start button a green light is on, 10 seconds later the green light goes off and a red light is turned on. The red light will then remain on until the stop button is pressed. (6 marks)

4(b) Modify and **redraw** the above control circuit such that 20 seconds after the red light is turned on, the whole sequence will restart. (4 marks)

5 A consumer unit has a single-line diagram as shown in Figure Q5. Determine the tripping times obtain from the Time/Current curve of the protective devices and state whether discrimination is achieved.

(i) When an overload current of 50A flows in Load1 (3 marks)

(ii) When a fault current of 125A occurs at Point A (3 marks)

(iii) When a fault current of 100A occurs at Point B (4 marks)

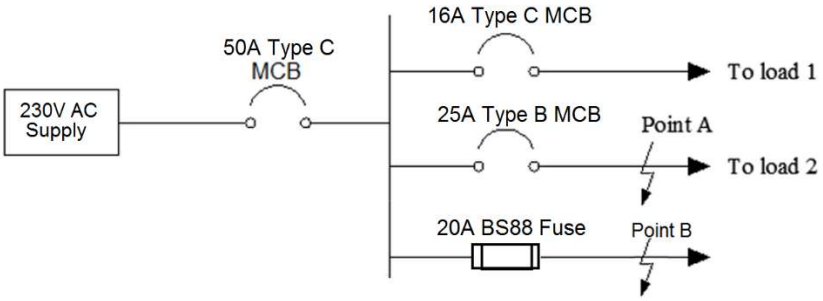

Figure Q5

6 Determine the earth fault loop impedance of the circuit in Figure Q6 at the 13A switched socket outlet. Is the value of the earth fault loop impedance acceptable for the 32A Type B MCB? Suggest a way to make the earth fault loop impedance acceptable. (10 marks)

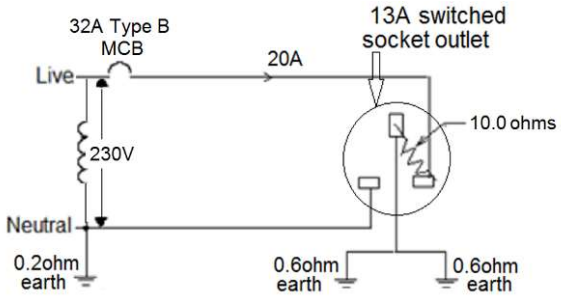

Figure Q6

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SECTION B : [20 Marks Each]

B1 A 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
- 10 nos. 13A switched socket outlet connected in **a ring circuit**, protected by a 32A MCB (Estimated demand of is 3.5kW)
- 20 nos. of 13A switched socket outlet connected in 2 radial ring circuits, each protected by a 20A MCB (Estimated demand of is 3.0kW)
- 3 nos. instantaneous water heaters, each rated 3 kW
- 2 no. storage water heater rated 1.5kW
- 5.5kW cooker connected to cooker control unit with switched socket outlet
- Multi-split air-conditioning unit where the electrical load is to be considered as a three-phase motor, rated 9.5 kW with an efficiency of 85% and a power factor of 0.86.

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

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) A 3 phase 400V motor is rated 9 kW at power factor of 0.85 lagging and efficiency of 90%. The length of the cable from the distribution board is 60m. It is wired in single-core PVC insulated copper cable sharing a trunking with one other similar circuit. The ambient temperature is 40^0 C. Determine:

(i) The operating current of the motor, hence the nominal rating of the **Type B MCB**. (2 marks)
(Standard circuit breaker rating: 15A, 20A, 25A, 30A, 32A, 40A, 50A, 63A)

(ii) A suitable cross section area of the cable. (6 marks)

(iii) The actual voltage drop and check whether the cable size selected can meet the CP5 requirement. Re-select cable size if necessary. (3 marks)

B2(b) A single-phase 230V, cooking appliance is wired in single-core 4.0mm**²** PVC insulated copper conductor and 2.5mm^2 PVC insulated copper conductor for circuit protective conductor. The circuit is protected by a 25A Type B MCB, the circuit length is 20 meters long. The value of Z_E is given as 0.8 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 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 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 4D1A

Single-core pvc-insulated cables, non-armoured, with or without sheath

(COPPER CONDUCTORS) BS6004, BS6231, BS6346

Ambient temperature: 30°C

CURRENT-CARRYING CAPACITY (amperes) Conductor operating temperature: 70°C

Conductor cross-sectional area	Reference Method 4 (enclosed in conduit in thermally insulating wall etc.)		Reference Method 3 (enclosed in conduit on a wall or in trunking etc.)		Reference Method 1 (clipped direct)		Reference Method 11 (on a perforated cable tray horizontal or vertical)		Reference Method 12 (free air)		
									Horizontal flat spaced	Vertical flat spaced	Trefoil
	2 cables single phase a.c or d.c.	3 or 4 cables three phase a.c.	2 cables single phase a.c. or d.c.	3 or 4 cables three phase a.c.	2 cables single phase a.c. or d.c. flat and touching	3 or 4 cables three phase a.c. flat and touching or trefoil	2 cables single phase a.c. or d.c. flat and touching	3 or 4 cables three phase a.c. flat and touching or trefoil	2 cables single phase a.c. or d.c. or 3 cables three phase a.c.	2 cables single phase a.c. or d.c. or 3 cables three phase a.c.	3 cables trefoil. three phase a.c.
2	3	4	5	6	7	8	9	10	11	12	
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	11	10.5	13.5	12	15.5	14	-	-	-	-	-
1.5	14.5	13.5	17.5	15.5	20	18	-	-	-	-	-
2.5	20	18	24	21	27	25	-	-	-	-	-
4	26	24	32	28	37	33	-	-	-	-	-
6	34	31	41	36	47	43	-	-	-	-	-
10	46	42	57	50	65	59	-	-	-	-	-
16	61	56	76	68	87	79	-	-	-	-	-
25	80	73	101	89	114	104	126	112	146	130	110
35	99	89	125	110	141	129	156	141	181	162	137
50	119	108	151	134	182	167	191	172	219	197	167
70	151	136	192	171	234	214	246	223	281	254	216
95	182	164	232	207	284	261	300	273	341	311	264

TABLE 4D1B

VOLTAGE DROP (per ampere per metre) Conductor operating temperature: 70°C

Conductor cross-sectional area	Two cable, d.c.	Two cable, single phase a.c.			Three or four 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

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

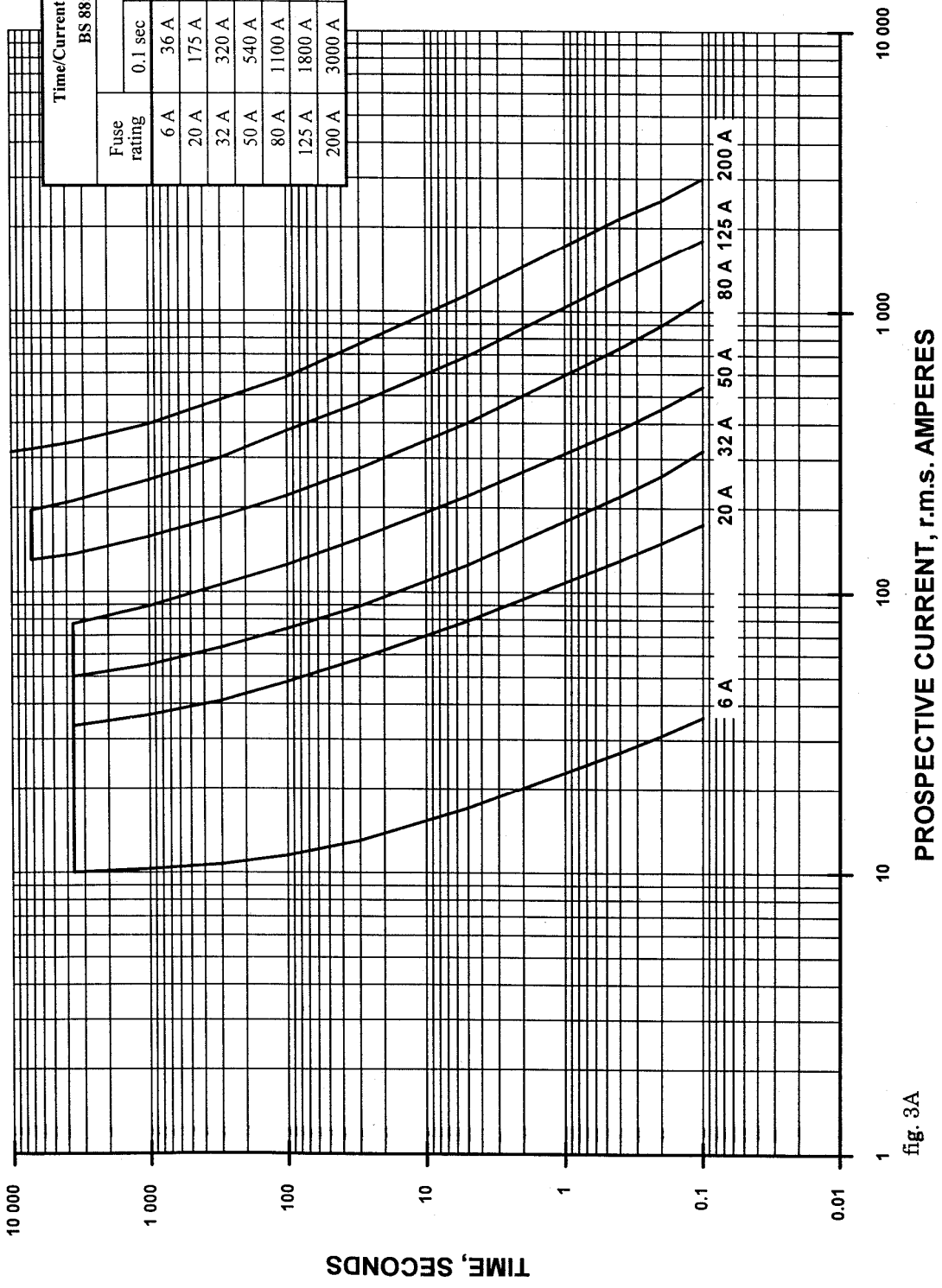

fig. 3A

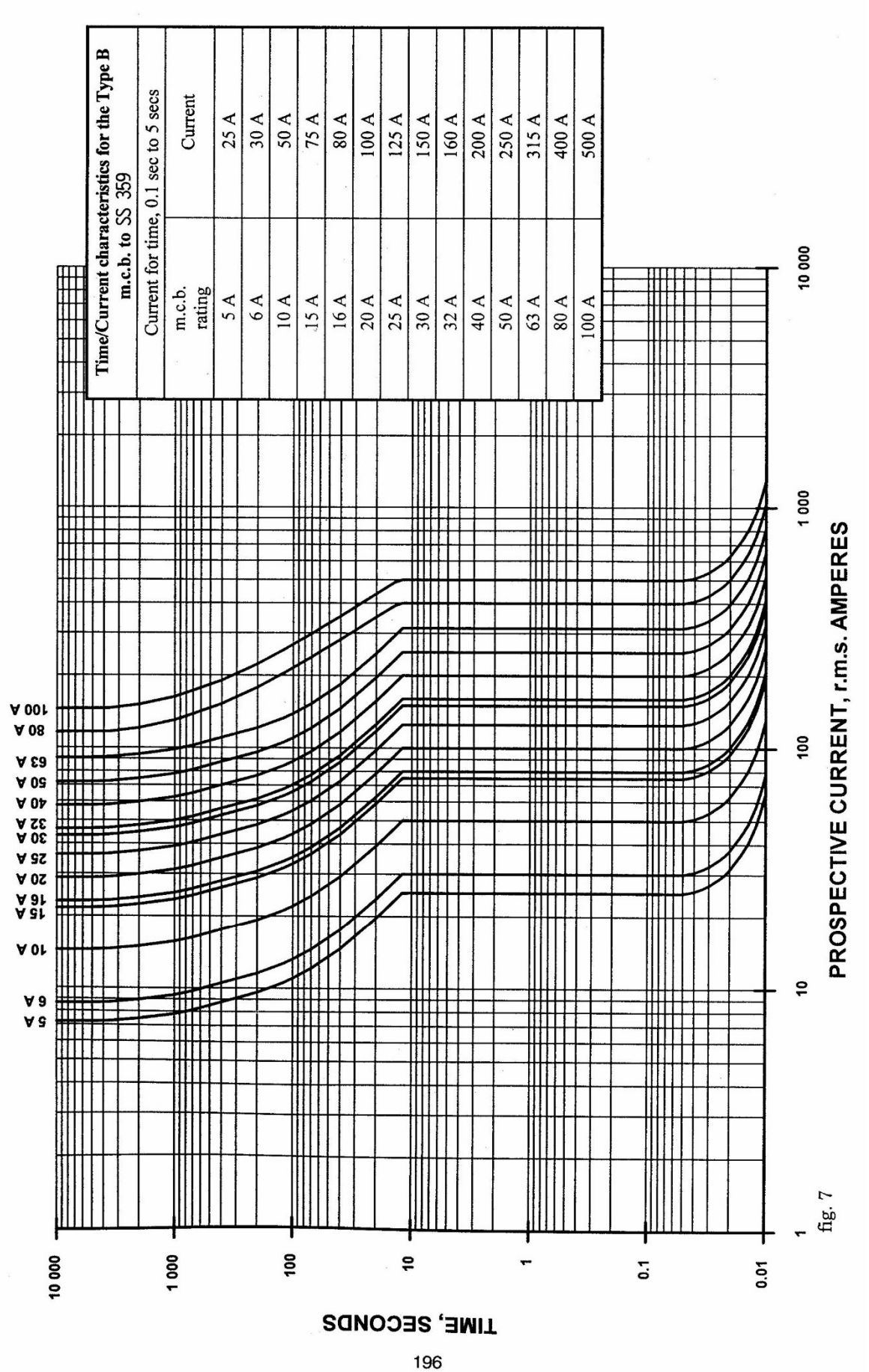
Time/Current characteristics for the Type B m.c.b. to SS 359
Current for time, 0.1 sec to 5 secs
m.c.b. rating
Current
5 A
25 A
6 A
30 A
10 A
50 A
15 A
75 A
16 A
80 A
20 A
100 A
25 A
125 A
30 A
150 A
32 A
160 A
40 A
200 A
50 A
250 A
63 A
315 A
80 A
400 A
100 A
500 A
TIME, SECONDS
10 000
1 000
100
10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

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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.