SINGAPORE POLYTECHNIC ET0050

2019/2020 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 shopping centre needs **1800kW** 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 1800kW? (6 marks)

1(b) An operating theatre in a hospital uses electrical separation to prevent single fault to earth from tripping the operating theatre power supply. State the key equipment used and what is being separated? (4 marks)

2 Explain briefly the purpose of Socket Outlet Assembly (SOA) for use in Temporary Electrical Installations. 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 minimum inspection frequency required for a temporary installation in a night market. (10 marks)

3(a) In the context of electric shock, explain what is "direct contact" and "indirect contact"? State the two most common measures used for protection of person(s) against indirect contact. (6 marks)

3(b) In the circuit below four resistors are connected to a 400V/230V three phase supply. Calculate current I_1. It is also given that I_2 is equal to I_1 determine Rx and V_R. (4 marks)

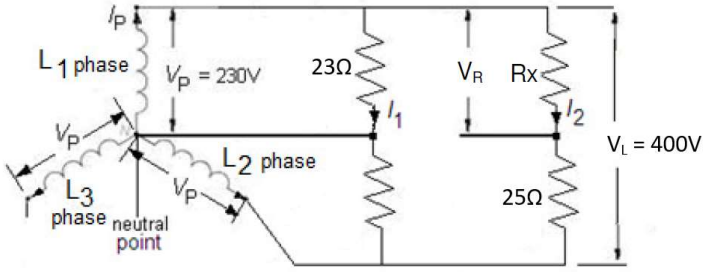


Figure Q3(b)

4 Modify the control circuit shown in Figure Q4 to provide for additional remote Stop and Start in two other locations. (10 marks)

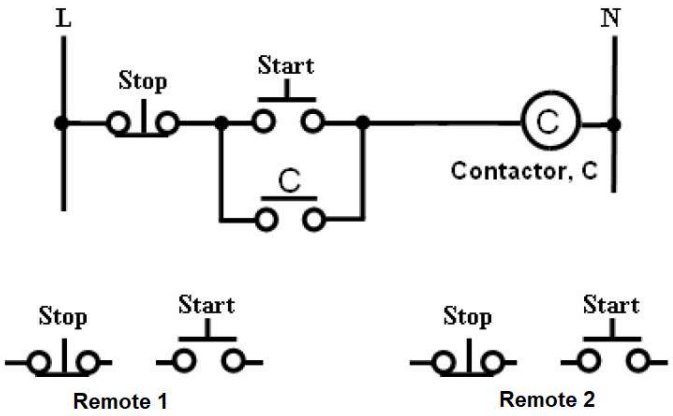


Figure Q4

5 An electrical distribution board 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 100A flowing in Load1 (3 marks)

(ii) When a fault current of 165A occurs at Point A (3 marks)

(iii) When a fault current of 320A occurs at Point B (4 marks)

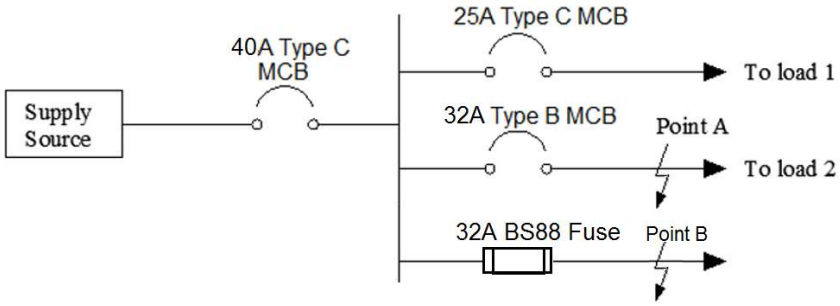


Figure Q5

6(a) An electrical installation with 500 points/outlets was measured at the main switchboard for the Insulation Resistance Test. The values obtained are 0.4MΩ, 0.4MΩ and 0.4MΩ from Brown, Black and Grey phase to the Neutral. What is the minimum acceptable minimum insulation resistance value in CP5: 1998? Explain whether it is acceptable for this installation, give reason(s) for your explanation? (5 marks)

6(b) Besides the insulation resistance test, name any other five tests that must be carried out before energising an electrical installation in Singapore.

(5 marks)

SECTION B : [20 Marks Each]

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

- 30 nos. 2 x 32W fluorescent lamps
- 80 nos. 13A switched socket outlet connected in **4 ring circuits**, each protected by a 32A MCB (Estimated demand of each circuit is 4kW)
- 1 no. storage water heater rated 1.2kW
- 1 no. instantaneous water heater rated 2.5kW
- 1400W video projector system supplied from a13A switched socket outlet
- Multi-split air-conditioning unit where the electrical load is to be considered as a three-phase motor, rated 15 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 Type B MCB for the main circuit breaker, assuming 25% spare capacity is allowed for future expansion
(Standard circuit breaker rating: 20A, 25A, 30A, 40A, 50A, 63A, 80A, 100A).

(iii) Select an appropriate size Type B MCB for the three phase air-conditioning motor. State the measure required for the motor for protection against indirect contact.

(19 marks)

B2(a) Two electric furnaces each 25kW operate side by side. They are operated at the same time throughout the day. The furnaces require 3-phase 400V at unity power factor. The run of the single-core PVC insulated copper cables from the main switchboard is about 20metres. The cables shared a single trunking. The ambient temperature can rise to 30^0 C. Determine:

(i) The operating current of one of the furnaces, hence the nominal rating of the Type B 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 appliance is wired in single-core 6.0mm^2 PVC insulated copper conductor and 2.5mm^2 PVC insulated copper conductor for circuit protective conductor. The circuit is protected by a 40A Type B MCB, the circuit length is 10 meters long. The value of Z_E is given as 0.65 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

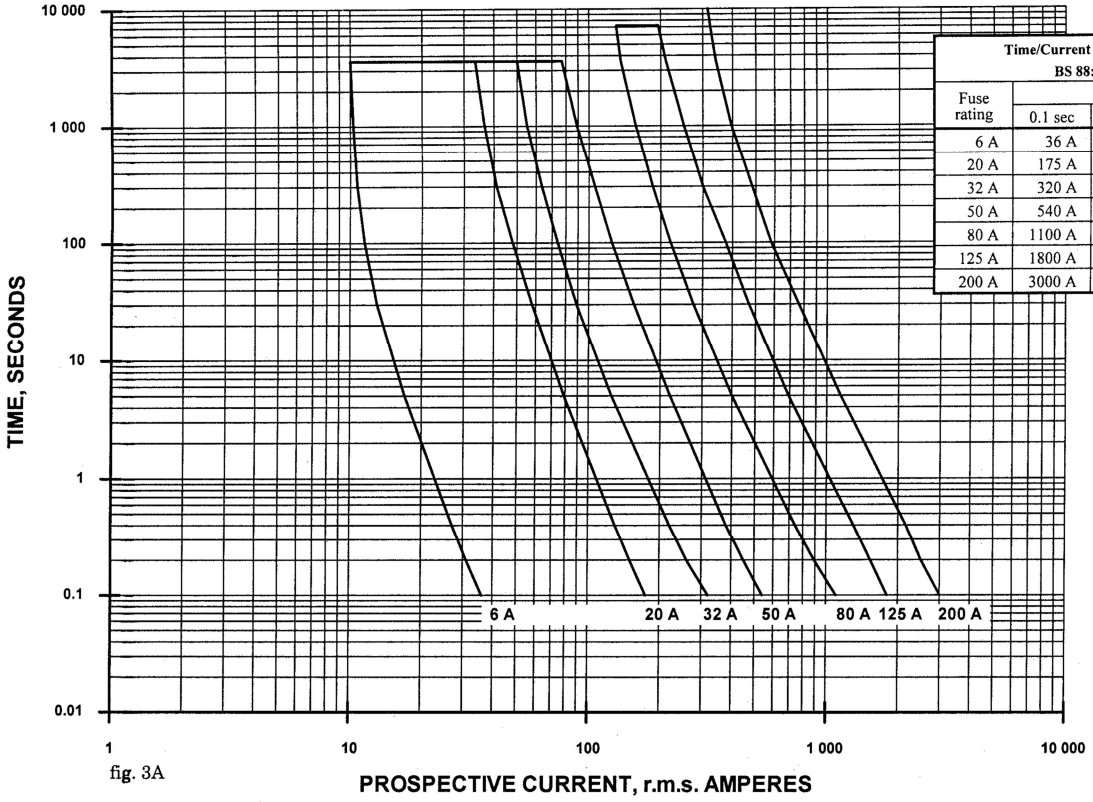
CURRENT-CARRYING CAPACITY (amperes) Conductor operating temperature: 70°C

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

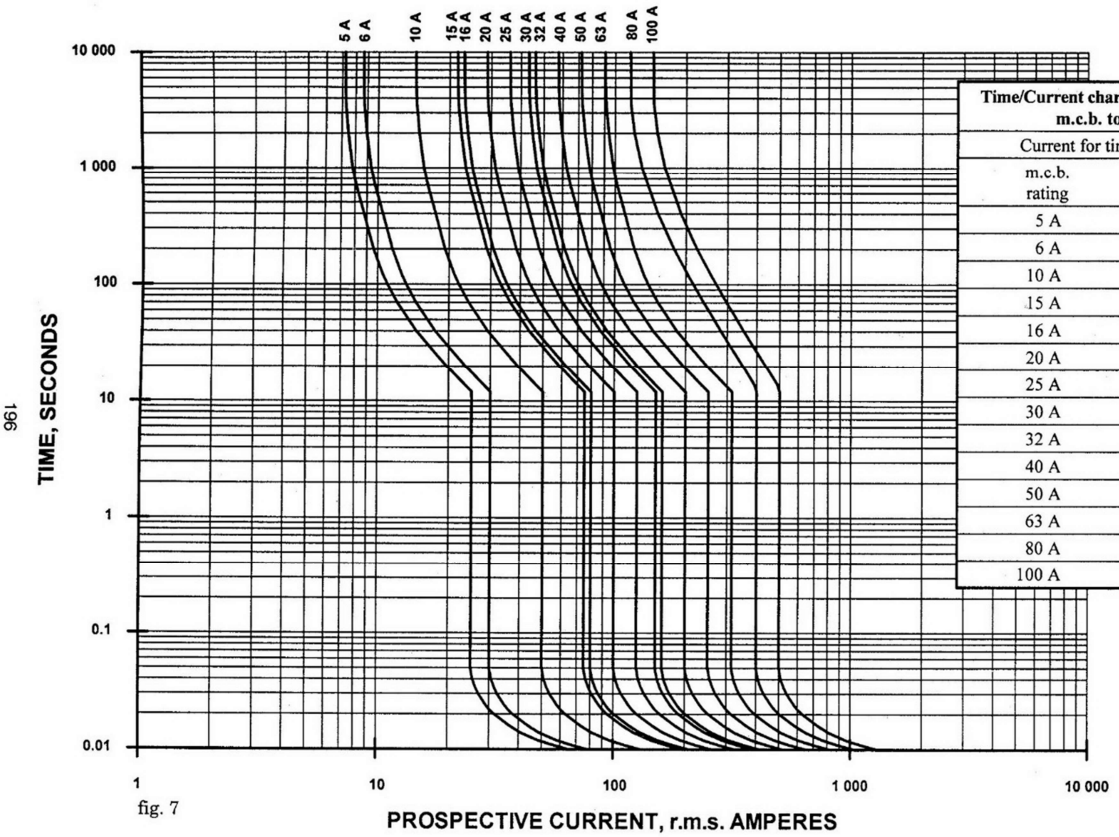
Conductor cross-sectional area	Two cable, d.c.	Two cable, single phase a.c.			Three or four cable, three phase a.c.		
1	2	3			4		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1	44	44			38		
1.5	29	29			25		
2.5	18	18			15		
4	11	11			9.5		
6	7.3	7.3			6.4		
10	4.4	4.4			3.8		
16	2.8	2.8			2.4		
		r	x	z	r	x	z
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

191

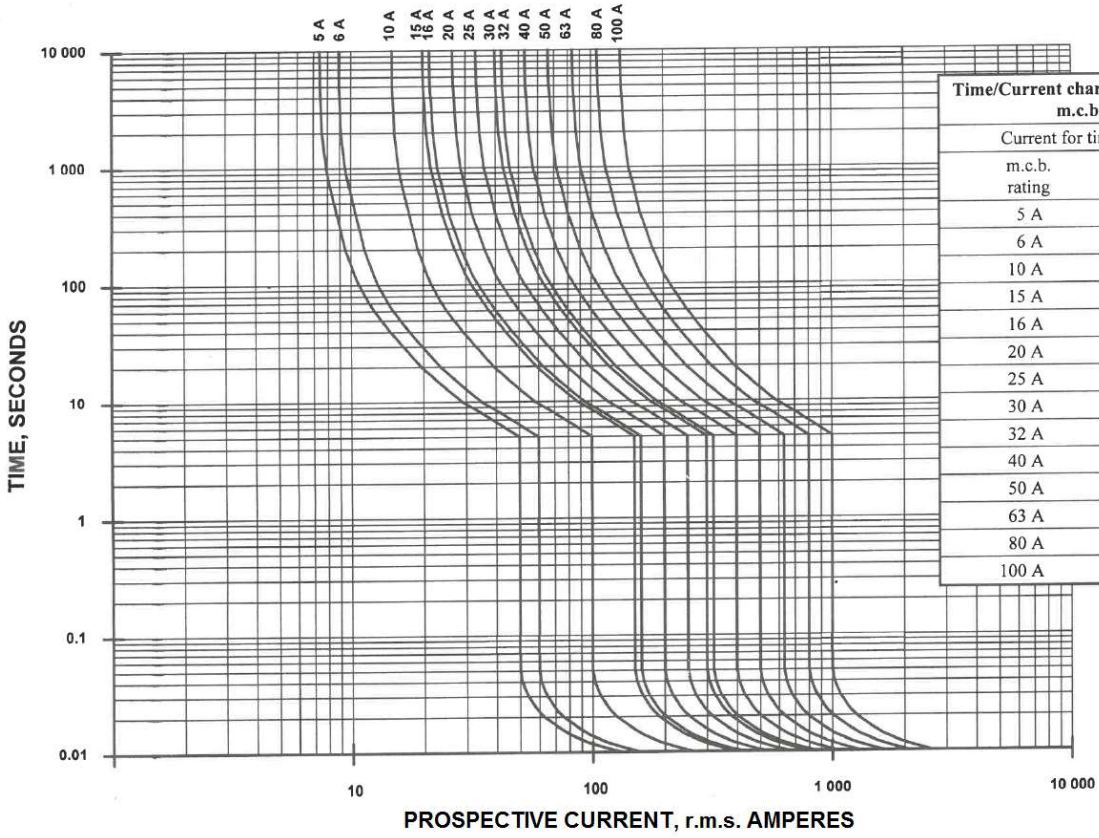
fig. 3A



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

196

fig. 7



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 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

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.