THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
HIGHER DIPLOMA IN TECHNOLOGY
ECX4234-ELECTRICAL INSTALLATION
FINAL EXAMINATION - 2015/2016

CLOSED BOOK

Date 22nd November 2016 Time: 09.30-12.30 hrs.

This paper contains 8 questions. Pages 4 to 8 contain appropriate tables and characteristic curves required for answering the questions. Answer only five (5) questions.

1. A 230 V, 12 kW domestic electric cooker is to be supplied by a 12 m run of dedicated PVC insulated and sheathed cable enclosed in conduit in thermally insulated wall. The circuit is protected by a type-B circuit breaker to BS60898 and the value of earth fault impedance external to the circuit is 0.85Ω. Determine the minimum size of the main cable and the appropriate earth wire size which can be used for the above installation? You may consider diversity of cooker load for computation of cable size. Assume k=115 for Cu conductors and the ambient temperature to be 30^0C. **[20 Marks]**

2. A circuit connected to an appliance with a resistance of 0.5 Ω is protected by a 20 A semi enclosed ceramic fuse to BS3036. The external earth fault loop impedance to this circuit is 0.8Ω and the source voltage is 230 V at 50 Hz. In case of a ground fault of effective resistance 1Ω is occurred across the load, using suitable assumptions and calculations, determine:
   a) The fault current **[4 Marks]**
   b) The time taken for the fuse to blow **[4 Marks]**
   c) The prospective fault voltage across the fault **[4 Marks]**
   d) The current that may flow through a typical human body if a person comes into contact with the fault at the load **[4 Marks]**
   e) What form of a shock is likely to happen to the person **[4 Marks]**

3. A single phase 230 V, electric appliance rated at 3 kW is to be fed from a distribution board over a distance of 10m with 2 bends. The PVC insulated copper (thermo-plastic) cable circuit recommended for this installation is enclosed in a conduit with 2 other similar size cable circuits embedded in a plastered brick work. The ambient temperature is 32 ^{0}C.

   a) Determine the design current for the appliance **[2 Marks]**
   b) Select, raring of the device if it is to be protected by type-B circuit breaker to BS EN60898 **[2 Marks]**
   c) Calculate the value C_a for computing the cable rating **[2 Marks]**
   d) What is the suitable value of C_g for computing the cable rating **[2 Marks]**
   e) Compute the required ampere rating of this cable **[3 Marks]**
   f) What should be its cross sectional area **[2 Marks]**
   g) What voltage would you experience at the appliance **[3 Marks]**
   h) What diameter would you recommend for the conduit if the laying incorporates two bends **[2 Marks]**
   i) Calculate the minimum value for bending radius **[2 Marks]**

4. Conceptual single line diagram of a certain installation is as shown in Figure Q4.

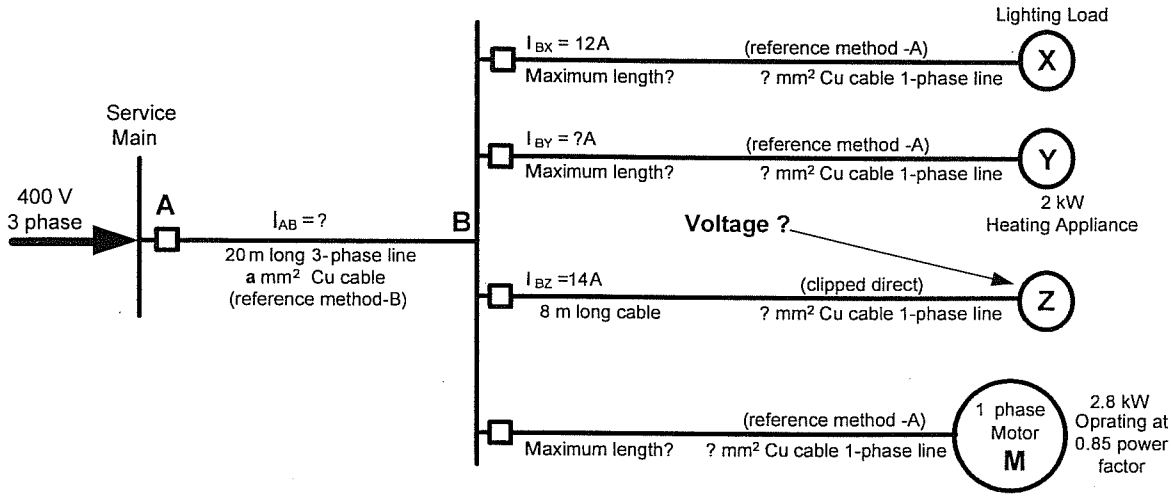


Figure Q4

A 3-phase service main of **"a"** mm^2 and a length of 20 meter supplies a symmetrical 3 sets of identical X, Y, Z & 1-phase motor loads connected to 3-phases emanating from bus-bar B (only a single set of loads connected to one phase is shown in figure Q4 for clarity and simplicity). Permissible voltage drop allowed from A to each destination of load is 2.5%.

Compute the following:

a) Line current (I_{AB}) flowing in the three phase line AB? **[3 Marks]**

b) Appropriate cable size **"a"** for three phase line AB? **[2 Marks]**

c) Voltage at bus bar B? **[3 Marks]**

d) Size of the cable BX and its maximum length? **[3 Marks]**

e) Current flowing through cable BY, its size and the maximum length of BY? **[3 Marks]**

f) Size of the cable BZ and the voltage at Z? **[3 Marks]**

g) Size of the cable supplying **M** motor load and its maximum length? **[3 Marks]**

5. a) Explain the term 'Earth resistivity of a Soil' **[4 Marks]**

b) What are the soil conditions that are preferable for the location of a consumer earth electrode? **[4 Marks]**

c) Indicate methods available for lowering the earth resistance of an 'Earth Electrode' **[4 Marks]**

d) It is required that the earth electrode resistance be not more than 2Ω at a particular location. The measured value of the 'Earth resistance' of the electrode is 15Ω. Explain how you would use an array of similar electrodes to have the desired earth resistance value for the combine system. **[4 Marks]**

e) What factors would affect your solution (d) against the practical solution. **[4 Marks]**

6. a) What would be the maximum current carrying capacity of 1/1.38 (1.5 mm^2) **p.v.c.** cable (in conduit) used in domestic wiring? **[2 Marks]**

   b) State the adiabatic equation and identify the parameters with units **[2 Marks]**

   c) What is the sensitivity of domestic RCCB and state the time duration within which it should operate? **[2 Marks]**

   d) State maximum percentage voltage drop you would allow in a circuit from its distribution board for a domestic electrical installation as per the 17^{th} edition of the IEE wiring regulations? **[2 Marks]**

   e) You are given a conduit occupied by two 1/1.13 wires running in a circuit. For how long the wire can run if the maximum current allowed is 7.5 A. **[2 Marks]**

   f) How many 2.5 mm^2 single core cables that can be occupied in a 16 mm **p.v.c.** conduit pipe in a straight-run (without bends) domestic wiring? **[2 Marks]**

   g) State the insulation resistance value you would expect for a good domestic electrical installation in Sri Lanka? **[2 Marks]**

   h) What would be the IP code of an electric bell-push installed outside a typical domestic premises in Sri Lanka where exposed for rain water? **[2 Marks]**

   i) A 230V, 3/4 hp water pump operating at 0.85 lagging power factor located about 8 m away from the distribution board is protected by a type-B circuit breaker to BS60898. What cable size would you recommend for this circuit? Assume 1.0 for all the correction factors. **[2 Marks]**

   j) What maximum earth fault loop impedance would you allowed, for a circuit protected by a 30 A semi-enclosed ceramic fuse to BS3036 in order to operate it at 0.4 s? **[2 Marks]**

7. a) What are the devices used in an electrical installation for protective purposes and indicate the types of protection provided by these devices? **[5 Marks]**

   b) What is meant by the 'prospective fault current' as applicable to an electrical installation? **[5 Marks]**

   c) A supply to a domestic installation is to be provided from a point in a distribution network where the 'prospective fault current' is 3500 A. Determine the maximum value of the earth loop impedance at the input point of the installation if the installation is protected by a 63 A rated, type-B circuit breaker to BS60898. **[10 Marks]**

8. a) Why is the IEE regulation specify that we must use one-quarter (1/4) of the total impedance of a ring circuit measured between disconnected ends when calculating the earth fault loop impedance? **[10 marks]**

   b) A single-phase ring circuit is run in 2.5 mm^2 70 ^{0}C PVC-insulated and sheathed flat cable with a protective conductor of cross sectional area 1.5 mm^2. If the circuit length is 65 m long and Z_E = 0.35 Ohm (Z_E = earth fault loop impedance external to the installation), what is the earth fault loop impedance of the circuit? Also, check whether the circuit is in compliance with the adiabatic equation? Assume K=115 & t = 0.04 s.
   Assume that the resistance of (2.5 mm^2 +1.5 mm^2)/meter length = 0.03 Ω/m **[10 marks]**

Rating factor (C_a) table for ambient temperature correction

Ambient Temp. ^{0}C	Insulation 70 ^{0}C thermoplastic	Insulation 90 ^{0}C thermosetting
25	1.03	1.02
30	1.00	1.00
35	0.94	0.96
40	0.87	0.91
45	0.79	0.87
50	0.71	0.82
55	0.61	0.76
60	0.50	0.71

Rating factor (C_g) table for one circuit or for a group of circuits

Arrangement of cables (touching)	Number of circuits or multicore cables												Laying Methods Reference
	1	2	3	4	5	6	7	8	9	12	16	20	
Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38	Methods A to F
Single layer on wall or floor	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	0.70	0.70	0.70	Method C
Single layer multicore on a perforated horizontal or vertical cable tray system	1.00	0.88	0.82	0.77	0.75	0.73	0.72	0.72	0.72	0.72	0.72	0.72	Methods E & F
Single layer multicore on cable ladder system or cleats.	1.00	0.87	0.82	0.80	0.80	0.79	0.79	0.78	0.78	0.78	0.78	0.78	

FACTORS FOR TRUNKING

Cable factors for Tunking

Type of conductor	Conductor cross-sectional area mm^2	Factor
Solid	1	7.1
	2.5	10.2
Stranded	1.5	8.1
	2.5	11.4
	4	15.2
	6	22.9
	10	36.3

Factor for Trunking

Dimension of trunking (mm x mm)	Factor	Dimension of trunking (mm x mm)	Factor
50 x 37.5	767	100 x 37.5	1542
50 x 50	1037	100 x 50	2091
75 x 25	738	100 x 75	3189
75 x 37.5	1146	100 x 100	4252
75 x 50	1555		
75 x 75	2371		
100 x 25	993		

Source: IEE wiring Regulations 17th & 15th edition

FACTORS FOR CONDUITS

Cable Factors for straight runs ≤ 3 m

Type of conductor	Conductor cross-sectional area mm²	Factor
Solid	1	22
	1.5	27
	2.5	39
Stranded	1.5	31
	2.5	43
	4	58
	6	88
	10	146

Conduit factors for straight runs ≤ 3 m

Conduit diameter (mm)	Factor
16	290
20	460
25	800
32	1400

Cable factors for long straight runs > 3 m or runs incorporating bends

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

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	290	460	800	1400	188	303	543	947	177	286	514	900	158	256	463	818	130	213	388	692
1.5	290	460	800	1400	182	294	528	923	167	270	487	857	143	233	422	750	111	182	333	600
2	290	460	800	1400	177	286	514	900	158	256	463	818	130	213	388	692	97	159	292	529
2.5	290	460	800	1400	171	278	500	878	150	244	442	783	120	196	358	643	86	141	260	474
3	290	460	800	1400	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								

Source: IEE wiring Regulations 15th edition

Table 4D1A – Single-core 70°C thermoplastic insulated cables, non-armoured, with or without sheath (COPPER CONDUCTORS)

Ambient temperature: 30 °C

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

Conductor Cross Sectional area	Reference Method A (Enclosed in conduit in thermally insulating wall etc.)		Reference Method B (Enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray horizontal or vertical)				
							Touching			Spaced by one diameter	
	2 cables. 1Φ a.c. or d.c.	3 or 4 cables. 3Φ a.c.	2 cables. 1Φ a.c. or d.c.	3 or 4 cables. 3Φ a.c.	2 cables. 1Φ a.c. or d.c. flat & touching	3 or 4 cables. 3Φ a.c. flat & touching or trefoil	2 cables. 1Φ a.c. or d.c. flat	3 cables. 3Φ a.c. flat	3 cables. 3Φ a.c. trefoil	2 cables, 1Φ a.c. or d.c. or 3 cables 3Φ a.c. flat	
										Horizontal	Vertical
mm^2	Amps.	Amps.	Amps.	Amps.	Amps.	Amps.	Amps.	Amps.	Amps.	Amps.	Amps.
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	131	114	110	146	130
35	99	89	125	110	141	129	162	143	137	181	162
50	119	108	151	134	182	167	196	174	167	219	197
70	151	136	192	171	234	214	251	225	216	281	254
95	182	164	232	207	284	261	304	275	264	341	311
120	210	188	269	239	330	303	352	321	308	396	362
150	240	216	300	262	381	349	406	372	356	456	419
185	273	245	341	296	436	400	463	427	409	521	480
240	321	286	400	346	515	472	546	507	485	615	569
300	367	328	458	394	594	545	629	587	561	709	659

Table 4D1B – Single-core 70°C thermoplastic insulated cables, non-armoured, with or without sheath (COPPER CONDUCTORS)

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

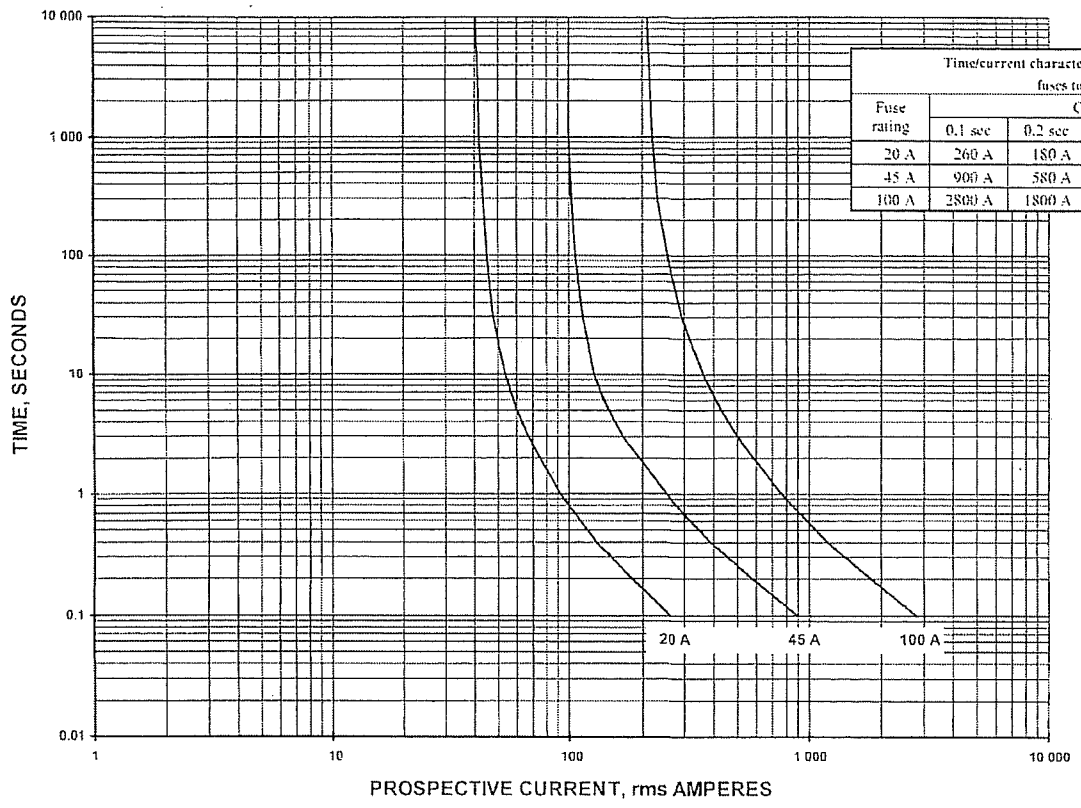
Conductor Cross Sectional area	2 cables 1Φ a.c.			3 or 4 cables, 3 Φ a.c.		
	Reference Methods A & B (Enclosed in conduit or trunking)	Reference Methods C & F (clipped direct, on tray or in free air)		Reference Methods A & B (Enclosed in conduit or trunking)	Reference Methods C & F (clipped direct, on tray or in free air)	
		Cables touching	Cables spaced		Cables touching, Trefoil	Cables touching, Flat	Cables spaced*, Flat
mm^2	mV/Amp/meter	mV/Amp/meter	mV/Amp/meter	mV/Amp/meter	mV/Amp/meter	mV/Amp/meter	mV/Amp/meter
1	44	44	44	38	38	38	38
1.5	29	29	29	25	25	25	25
2.5	18	18	18	15	15	15	15
4	11	11	11	9.5	9.5	9.5	9.5
6	7.3	7.3	7.3	6.4	6.4	6.4	6.4
10	4.4	4.4	4.4	3.8	3.8	3.8	3.8
16	2.8	2.8	2.8	2.4	2.4	2.4	2.4

	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.80	0.33	1.80	1.75	0.20	1.75	1.75	0.29	1.80	1.50	0.29	1.55	1.50	0.175	1.50	1.50	0.25	1.55	1.50	0.32	1.55
35	1.30	0.31	1.30	1.25	0.195	1.25	1.25	0.28	1.30	1.10	0.27	1.10	1.10	0.170	1.10	1.10	0.24	1.10	1.10	0.32	1.15
50	0.95	0.30	1.00	0.93	0.190	0.95	0.93	0.28	0.97	0.81	0.26	0.85	0.80	0.165	0.82	0.80	0.24	0.84	0.80	0.32	0.85
70	0.65	0.29	0.72	0.63	0.185	0.66	0.63	0.27	0.69	0.56	0.25	0.61	0.55	0.160	0.57	0.55	0.24	0.60	0.55	0.31	0.63
95	0.49	0.28	0.56	0.47	0.180	0.50	0.47	0.27	0.54	0.42	0.24	0.48	0.41	0.155	0.43	0.41	0.23	0.47	0.40	0.31	0.51
120	0.39	0.27	0.47	0.37	0.175	0.41	0.37	0.26	0.45	0.33	0.23	0.41	0.32	0.15	0.36	0.32	0.23	0.40	0.32	0.30	0.44
150	0.31	0.27	0.41	0.30	0.175	0.34	0.29	0.26	0.39	0.27	0.23	0.36	0.26	0.15	0.30	0.26	0.23	0.34	0.26	0.30	0.40
185	0.25	0.27	0.37	0.24	0.170	0.29	0.24	0.26	0.35	0.22	0.23	0.32	0.21	0.145	0.26	0.21	0.22	0.31	0.21	0.30	0.36
240	0.195	0.26	0.33	0.185	0.165	0.25	0.185	0.25	0.31	0.17	0.23	0.29	0.16	0.145	0.22	0.16	0.22	0.27	0.16	0.29	0.34
300	0.160	0.26	0.31	0.150	0.165	0.22	0.150	0.25	0.29	0.14	0.23	0.27	0.13	0.14	0.19	0.13	0.22	0.25	0.13	0.29	0.32

1Φ – Single phase; 3Φ – Three phases; Note: * - Spacing larger than one cable diameter will result in a larger voltage drop.

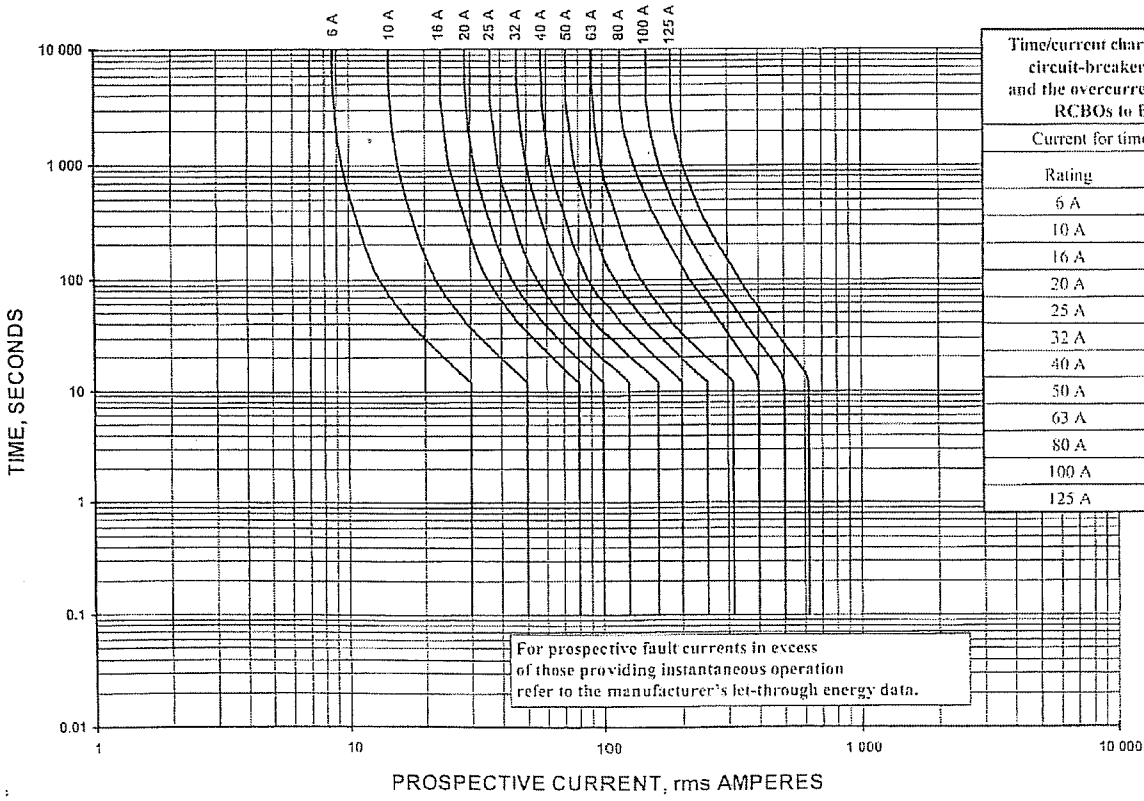
Source: IEE wiring Regulations 17th edition

BS 3036 fuse characteristics



Time/current characteristics for semi-enclosed fuses to BS 3036					
Fuse rating	Current for time				
	0.1 sec	0.2 sec	0.4 sec	1 sec	5 secs
20 A	260 A	180 A	130 A	92 A	60 A
45 A	900 A	580 A	390 A	250 A	145 A
100 A	2800 A	1800 A	1200 A	770 A	430 A

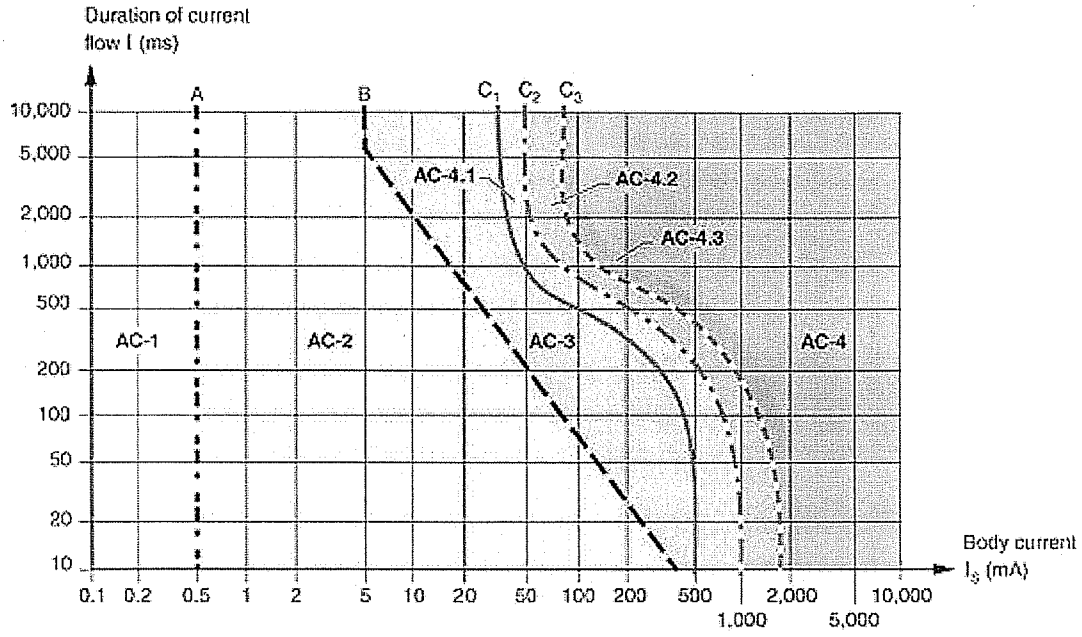
Type B circuit-breaker to BS EN 60898 and RCBOs to BS EN 61009-1 characteristics



Time/current characteristics for Type B circuit-breakers to BS EN 60898 and the overcurrent characteristics of RCBOs to BS EN 61009-1	
Current for time, 0.1 sec to 5 secs	
Rating	Current
6 A	30 A
10 A	50 A
16 A	80 A
20 A	100 A
25 A	125 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
125 A	625 A

Source: IEE wiring Regulations 17th edition

Time/Current zones of ac effects (15 -100 Hz) on persons



AC-1 zone: Imperceptible: No sensation at all or negligible feeling
AC-2 zone: Perceptible: Prickling sensation and possibly painful effect on muscles of fingers and arms, there is no harmful effect
AC-3 zone: Reversible effects: Respiratory trouble could occur, i.e. there are muscular contraction, cramp like pulling together of arms, difficulty in breathing, no danger of ventricular fibrillation (0.5% probability). This is generally the limit of tolerance.

AC-4 zone: Possibility of irreversible effects
AC-4-1 zone: Up to 5% probability of heart fibrillation
AC-4-2 zone: Up to 50% probability of heart fibrillation
AC-4-3 zone: More than 50% probability of heart fibrillation