00140

THE OPEN UNIVERSITY OF SRI LANKA
Faculty of Engineering Technology
Department of Electrical & Computer Engineering

Bachelor of Technology Honours in Engineering

Final Examination (2016/2017)
ECX4234: Electrical Installations

Closed Book

Date: 14th November 2017 (Tuesday) **Time: 9:30 am – 11:30 am**

This paper consists of two sections and 8 questions. Answer five questions selecting only one question from Section B. All questions carry equal marks. Attach pages 7 and 8 to your answer script if question #2 of section B is answered. Relevant figures and tables are attached to this question paper. Zero marks will be given if formulas used for the computation of factors for cable rating calculations.

Section A-Electrical Installation

1. a. List at least five factors affecting the current carrying capacity of a cable? **[5 Marks]**

   b. A PVC insulated and sheathed multi-core cable of 2.5 mm^2 feeding a 230 V, 3 kW heater is buried 15 meters along its length directly under the plaster. This cable is protected with a 15 A mcb. Due to some reason, the cable had to be replaced. The technician who did the job, without burring the new cable of the same size as the old one, passed through a conduit which carried five other multi core cables. Show that what the electrician has done is not safe. Assume ambient temperature is 32^0 C and there is no thermal insulation for walls. **[10 Marks]**

   c. What do you recommend him to do? **[5 Marks]**

2. A single phase 230 V, electric appliance rated at 3.75 kW operating at 0.85 power factor is to be fed from a distribution board over a distance of 10 m 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, rating of the device if it is to be protected by type-B circuit breaker to BS EN60898 **[3 Marks]**
   c. Calculate the value C_a for computing the cable rating **[3 Marks]**
   d. What is the suitable value of C_g for computing the cable rating? **[2 Marks]**
   e. Compute the required ampere rating for a suitable cable **[2 Marks]**
   f. What should be its cross-sectional area? **[2 Marks]**
   g. What voltage would you experience at the appliance end? **[2 Marks]**
   h. What diameter would you recommend for the conduit? **[2 Marks]**
   i. Calculate the minimum value for the conduit bending radius **[2 Marks]**

3. Conceptual single line diagram of a certain installation is as shown in Figure Q3.

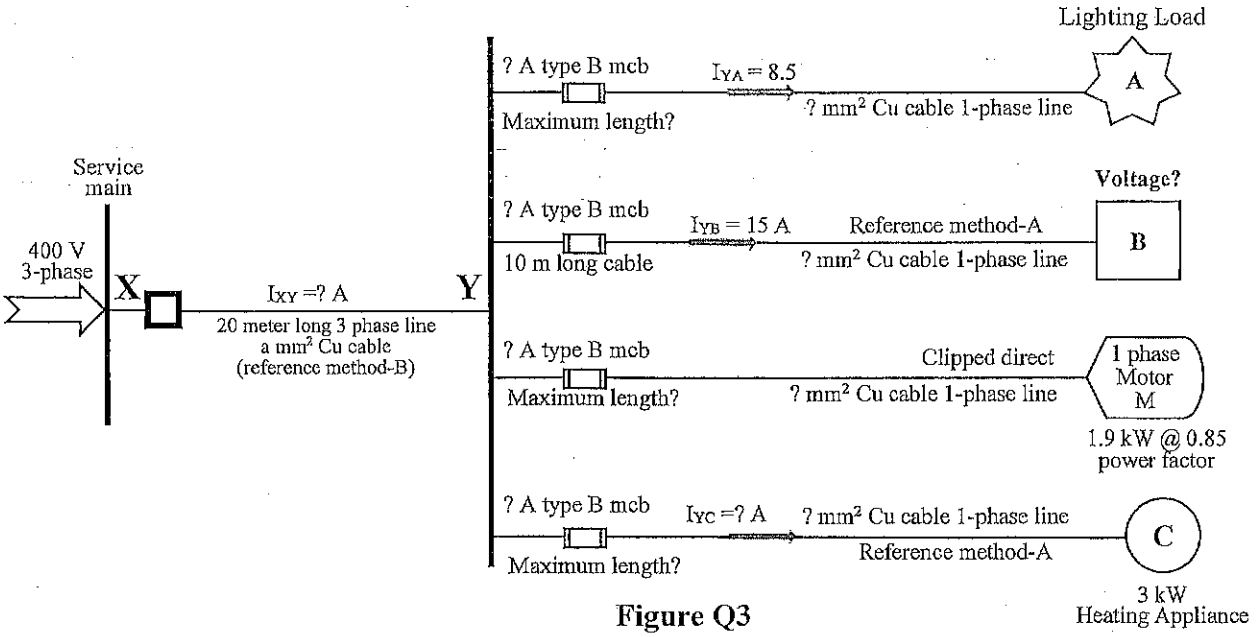


Figure Q3

A 3-phase service main of **"a"** mm² and a length of 20 meter supplies a symmetrical 3 sets of identical A, B, C and a 1-phase motor loads connected to 3-phases emanating from bus-bar Y (only a single set of loads connected to one phase is shown in figure Q3 for clarity and simplicity). Permissible voltage drop allowed from X to each destination of load is 2.5%.

Compute the following:

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

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

c. Voltage at bus bar Y? **[3 Marks]**

d. Size of the mcb, cable size YA and its maximum length? **[3 Marks]**

e. Size of the mcb, cable size YB and the voltage at B? **[3 Marks]**

f. Size of the mcb, cable size supplying **M** motor load and its maximum length? **[3 Marks]**
(you may assume that the starting current of the motor is twice that of the running current and the voltage drop of 5% is allowed at the start)

g. Size of the mcb and the current flowing through cable YC, its size and maximum length? **[3 Marks]**

4. **a.** You are given a conduit occupied by three 1.5 mm² similar cable circuits in a domestic installation. Find out the maximum cable length that can be run as per the IEE regulation, if the maximum current allowed to carry is 10A/circuit? **[2 Marks]**

b. How many 1 mm² single core cables that can be safely occupied in a 16 mm **p.v.c.** conduit pipe in a 10 m straight-run (without bends) domestic wiring? **[2 Marks]**

c. What insulation resistance value you would expect for a good domestic electrical installation in Sri Lanka? **[2 Marks]**

d. What is the next amendment of the IEE Regulation and the color of its cover page? **[2 Marks]**

e. State the approximate human body resistance under dry weather condition? **[2 Marks]**

f. State the single national standard **class** announced for plug and sockets outlets in Sri Lanka effective from 16th August 2016. **[2 Marks]**

g. What would be the maximum earth fault loop impedance value for a protection of an equipment operating at 240 V & protected by a 6A Type B-circuit breaker? **[2 Marks]**

h. An owner of a vehicle service centre interested in buying an outdoor electrical equipment. What IP code you would recommend to him? **[2 Marks]**

i. Determine a suitable rating of a fuse from BS3036, if an installation operates at 230 V with an earth loop impedance of 56 Ω and you are supposed to protect a fixed type equipment? **[2 Marks]**

j. 230V, 1/2 hp water pump operating at 0.8 lagging power factor located about 15 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 and the starting current is five times the running current. **[2 Marks]**

5. Figure Q5 shows different sizes of metal conduits joined to a metal trunking in an industrial electrical installation. Determine:

a. Appropriate size for the main trunking system **[3 Marks]**

b. Suitable size of the conduit for load 1 **[3 Marks]**

c. Bending Radius R_1 **[2 Marks]**

d. Suitable size of the conduit for load 2 **[2 Marks]**

e. Number of 6 mm² & 2.5 mm² (c.p.c) cables in conduit connecting 3 phase Load 3 **[3 Marks]**

f. Bending Radius R_2 **[2 Marks]**

g. Suitable size of the conduit for load 4 **[3 Marks]**

h. Bending Radius R_3 **[2 Marks]**

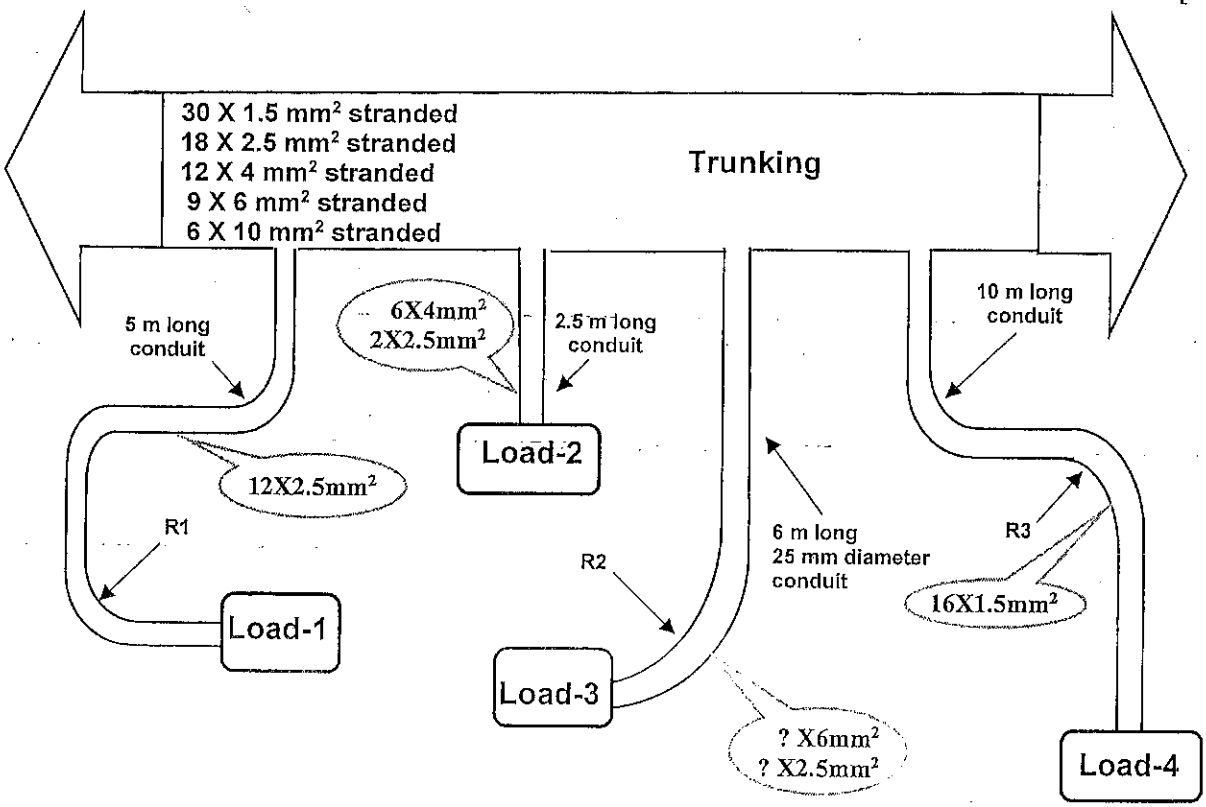


Figure Q5

6. **a.** To determine the earth fault loop impedance of a "spur" on a ring circuit, strictly it is necessary to estimate the fractional distance of that spur from the origin of the circuit. If the fraction is denoted by '*y*' as shown in figure Q6, prove that the earth fault loop impedance at the remote end of spur is given by:

$$Z_S = \left[Z_E + y(1-y)(R_{1T} + R_{2T}) + R_{1S} + R_{2S} \right] \text{ Ohm} \qquad \textbf{[6 Marks]}$$

Where:

R_{1T} = Total resistance of the phase conductor of the ring circuit in Ohm.

R_{2T} = Total resistance of the protective conductor of the ring circuit in Ohm.

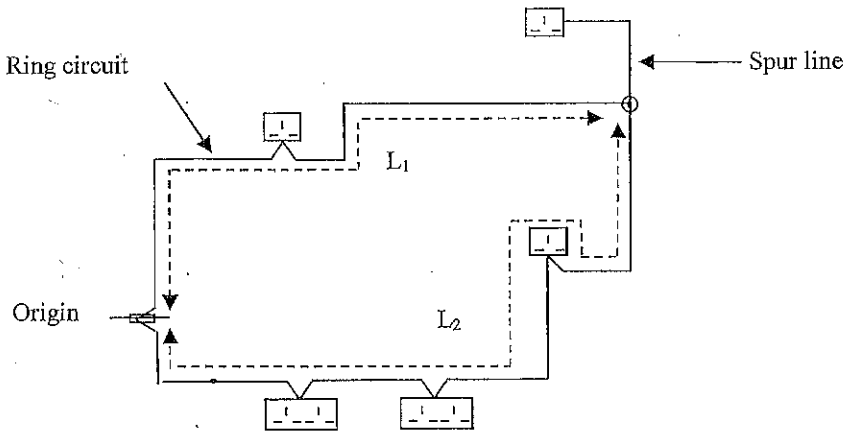
R_{1S} = Resistance of the phase conductor of the spur in Ohm.

R_{2S} = Resistance of the protective conductor of the spur in Ohm.

Z_E = Earth fault loop impedance external to the installation in Ohm.

b. Deduce that under the worst-case scenario, the above computed value would be:

$$Z_S = \left[Z_E + 0.25(R_{1T} + R_{2T}) + R_{1S} + R_{2S} \right] \text{ Ohm} \qquad \textbf{[6 Marks]}$$



$$\frac{L_1}{L_1 + L_2} = y$$

Figure Q6

c. A single-phase ring circuit is run in 2.5 mm^2 70 ^{0}C p.v.c-insulated and sheathed flat cable with the protective conductor being 1.5 mm^2. Measured length of the ring circuit is about 100 m. A spur taken from the ring is run in the same cable and the length of the spur being 10 m. If the spur is taken from the ring is 40 m from the origin and Z_E = 0.45, what is the earth fault loop impedance for the spur line? **[4 Marks]**

d. Explain the variation of the calculated value in 6.**b,** if the point where the spur is taken from the ring circuit varies around the circuit? To get a pessimistically high result for you to be on the safe side, what would be the highest value of the earth fault loop impedance you would estimate for 10 m spur in above ring circuit? **[4 Marks]**

Section B-Lighting and Illumination

1. Figure Q1a shows the layout of a commercial building. All the dimensions are given in meters. Building is 4 m height with white walls. 40W fluorescent tube lights (having 2400 lumen output) with twin tube fitting is proposed to be used as the light fitting. Photometric data of a light fitting is given in Figure Q1b and Table Q1a. Design a lighting scheme for given building with lighting layout by filling Q1b as required. Clearly state any assumption made during your calculations.

[20 marks]

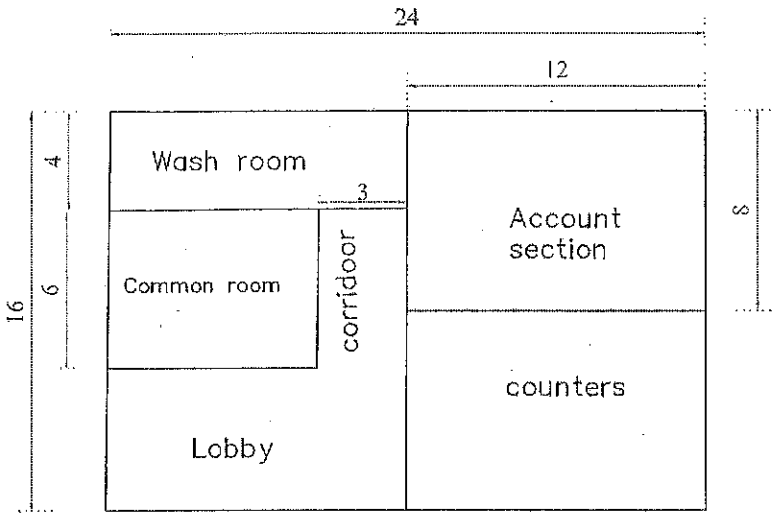


Figure Q1a Building Layout

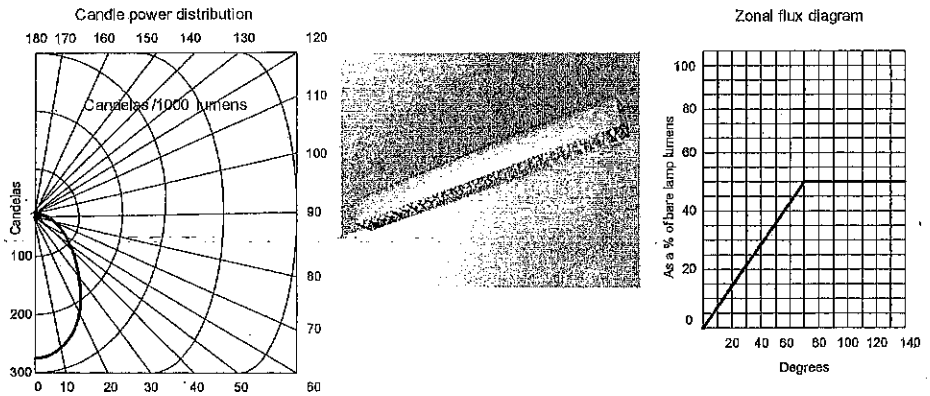


Figure Q1b Recess type with louvered over for Twin fluorescent (2 X 40W) lamp

Cont.....

Table Q1a Coefficient of Utilization

Room Reflectance (%)			ROOM INDEX									
Floor	Ceiling	Wall	0.6	0.8	1.0	1.25	1.5	2.0	2.5	3.0	4.0	5.0
10	**70**	50	0.28	0.33	0.36	0.39	0.41	0.44	0.45	0.46	0.48	0.49
		30	0.25	0.31	0.34	0.36	0.38	0.41	0.43	0.44	0.46	0.47
		10	0.23	0.28	0.31	0.34	0.36	0.39	0.41	0.43	0.45	0.46
10	**50**	50	0.28	0.33	0.36	0.38	0.40	0.42	0.44	0.45	0.47	0.48
		30	0.25	0.30	0.33	0.36	0.38	0.40	0.42	0.43	0.45	0.47
		10	0.23	0.28	0.31	0.34	0.36	0.39	0.41	0.42	0.44	0.46
10	**30**	30	0.25	0.30	0.33	0.36	0.37	0.40	0.42	0.43	0.45	0.46
		10	0.23	0.28	0.31	0.34	0.36	0.39	0.40	0.42	0.44	0.45

Table Q1b -Lighting design

Location	Average Illuminance Required E(Lux)	Length L (m)	Width W (m)	Mounting Height H (m)	Floor Area A(m^2)	Room Index	Utilization Factor	Maintenance. Factor	LLD	No of Lamps / luminaire	Lamp Luminous Flux (F)	Required no. of Luminaries	Proposed no of Luminaries(N)

2. Following are the multiple type questions. Underline the correct answer.

i. Candela is the unit of .....
   a. Wavelength
   b. Luminous intensity
   c. Luminous flux
   d. Illumination

ii. What will be the total flux emitted by a source of 60 candle power?
   a. 754.2 lumens.
   b. 0.00132 lumens
   c. 60 lumens
   d. None of these.

iii. In illumination technology, total lumens emitted by source / total lumens available after waste of light is equal to
   a. waste light factor.
   b. utilization factor.
   c. beam factor
   d. absorption factor

iv. The illumination at a point of 5 meters below a lamp is 6 lux. The candle power of the lamp is
   a. 30
   b. 140
   c. 150
   d. 200

v. Illumination can be expressed in
   a. radians.
   b. lux.
   c. lumens.
   d. candela

vi. Total flux or lumens required in any lighting scheme depends inversely on
   a. utilization factor
   b. reduction factor
   c. reflection factor
   d. none of the above

vii. The illumination of the surface varies directly with cosine of the angle between normal to surface and direction of the inclined light is given by
   a. law of square inverse
   b. Lambert's cosine law
   c. both A and B
   d. none of the above

viii. Which of the following will need the highest level of illumination?
   a. Proof reading
   b. Bed rooms
   c. Hospital wards
   d. Railway platforms.

ix. ..... factor is defined as the ratio of the illumination when everything is clean to illumination under normal working conditions
   a. Depreciation
   b. Maintenance
   c. Utilization
   d. Absorption factor.

x. Which of the following lamp gives nearly monochromatic light?
   a. Sodium vapor lamp
   b. GLS lamp
   c. Tube light
   d. Mercury vapor lamp.

Cont.....

xi. Luminous efficiency of a fluorescent tube is

a. 5- 10 lumens/watt
b. 15-20 lumens/watt
c. 30 - 40 lumens/watt
d. 60 - 65 lumens/watt

xii. The color temperature of day light is around

a. 50 K
b. 160 K
c. 600 K
d. 6000 K

xiii. Light is produced in electric discharge lamps by

a. heating effect of current
b. ionization in a gas or vapor
c. magnetic effect of current
d. carbon electrodes

xiv. Lumen/watt is the unit of

a. Light flux
b. Luminous intensity
c. Brightness
d. Luminous efficiency.

xv. When a sodium vapor lamp is switched on, initially the color is

a. Pink
b. Blue
c. Green
d. Yellow

xvi. According to Lambert's law, the illumination on a surface is proportional to

a. $\cos^2 \theta$
b. $\cos^3\theta$
c. $1/\cos^3\theta$
d. $1/\cos^2 \theta$.

[1.25*16 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
	1	2	3	4	5	6	7	8	9	12	16	20	Reference
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	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	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	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)

CURRENT-CARYING CAPACITY (amperes): Ambient temperature: 30 °C Conductor operating temperature: 70 °C

Conductor Cross Sectional area	Reference Method A (Enclosed in conduit in thermally insulating wall)		Reference Method B (Enclosed in conduit on a wall or in trunking)		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
mm²	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)

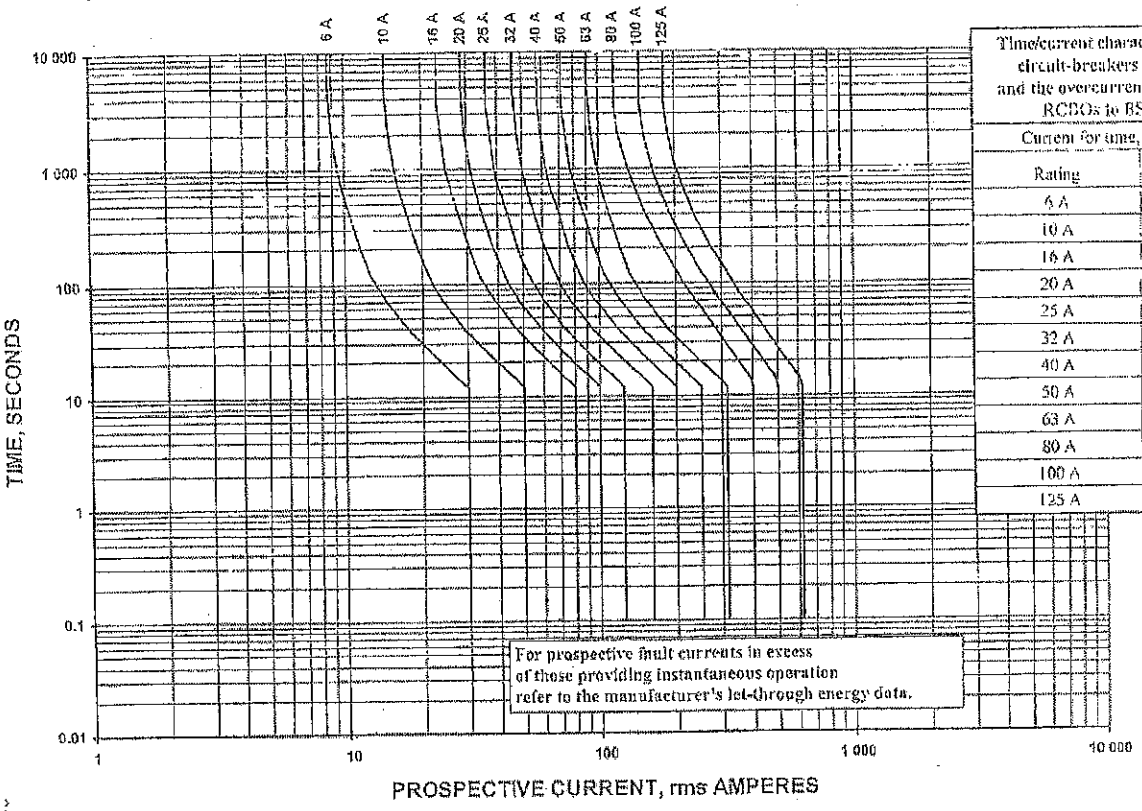
VOLTAGE DROP (per ampere per meter): Conductor operating temperature: 70 °C

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		
mm²	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.

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

BS 3036 Fuse characteristics