



Candidate Code No.	
For Board Use Only	
Result	Result
Date	Date
Int	Int

ELECTRICIAN'S THEORY EXAMINATION

20 June 2015

QUESTION AND ANSWER BOOKLET

Time Allowed: Three hours

INSTRUCTIONS – READ CAREFULLY

You have 10 minutes to read this paper but do not start writing until you are told to do so by the supervisor.

Write your Candidate Code Number in the box provided above. Your name must NOT appear anywhere on this paper.

Answer all questions.

The pass mark for this examination is 60 marks.

Use a pen for written answers. **Do not** use a pencil or a red pen.

Drawing instruments and pencils may be used when diagrams are required. Marks are allocated on the basis of correctness.

Do not use correcting fluid or correcting tape.

For calculation questions all workings, including formulae, must be shown to gain full marks.

Non-programmable calculators may be used.

Warning – You could get 0 marks for any question, or part of a question, if you show anything hazardous or dangerous in your answer.

Candidates are not permitted to use any Act, Regulation, Standard, Code of Practice, Handbook or other reference text in this examination.

PLEASE HAND THIS PAPER TO THE SUPERVISOR BEFORE LEAVING THE ROOM.

(turn over)

Question 1

- (a) State the reason why a residual current device (RCD) used for personal protection is required to switch both the phase and neutral poles?
(2 marks)

- (b) A three-phase, delta-connected induction motor is controlled by a DOL starter. The motor is protected by HRC fuses and a thermal overload.

State what would occur if one fuse blew (opened) while the motor was operating normally under full load.

(2 marks)

- (c) State the reason why a three-pole MCB would be used to protect a three-phase final subcircuit instead of three HRC fuses.
(2 marks)

(turn over)

Question 1 continued

- (d) A 400v, three-phase deep-fryer is rated at 15 kW.

Calculate maximum current that must be carried by the final subcircuit supplying the deep fryer.

(2 marks)

- (e) A 240V/230V heater draws 2500W when operating at 230V. Calculate the output power of the heater if the voltage drops 5%.

(2 marks)

- (f) (i) Describe the characteristics of a thermistor.

(1 mark)

- (ii) Where in a motor circuit would a thermistor be located?

(1 mark)

(turn over)

Question 1 continued

- (g) New mains have been installed in a 230V, single-phase domestic installation. During the work the phase and neutral were interchanged at the mains entry box.

State **TWO** hazardous situations that could arise if the installation was livened.

(2 marks)

(1) _____

(2) _____

- (h) Some protective devices on a switchboard in an electrical installation have a fault duty lower than the prospective short-circuit current rating of the installation.

State **TWO** hazards that could occur when a high prospective short-circuit fault current occurs in the electrical installation.

(2 marks)

(1) _____

(2) _____

(turn over)

Question 1 continued

(i) AS/NZS 3000 requires that a test voltage of 500V d.c. is used for an insulation resistance test of a low voltage electrical installation.

(i) Explain why a voltage of 500V is applied.

(1 mark)

(ii) Explain why the voltage is a d.c. voltage.

(1 mark)

(j) 100 metres of three-phase mains cable gave an insulation test result of $100\text{M}\Omega$. Calculate the insulation resistance of 500m of the same type of cable.

(2 marks)

(turn over)

Question 2

- (a) A DOL forward and reverse starter that controls a three-phase delta connected motor needs to be wired.

Draw and label the **power circuit** for the DOL starter. The drawing must show the contactors and conductors that enables the motor to be operated in the forward and reverse directions.

(4 marks)

(turn over)

Question 2 continued

- (b) Define the term **ramp-time** as it applies to a variable speed drive controlling a motor.

(1 mark)

- (c) A three-phase motor is controlled by a variable speed drive. The motor is required to operate at low speeds for extended periods.

What additional actions need to be taken in respect to the motor?

(2 marks)

- (d) State the reason why 6 conductors are required between a star/delta starter and a three-phase motor

(2 marks)

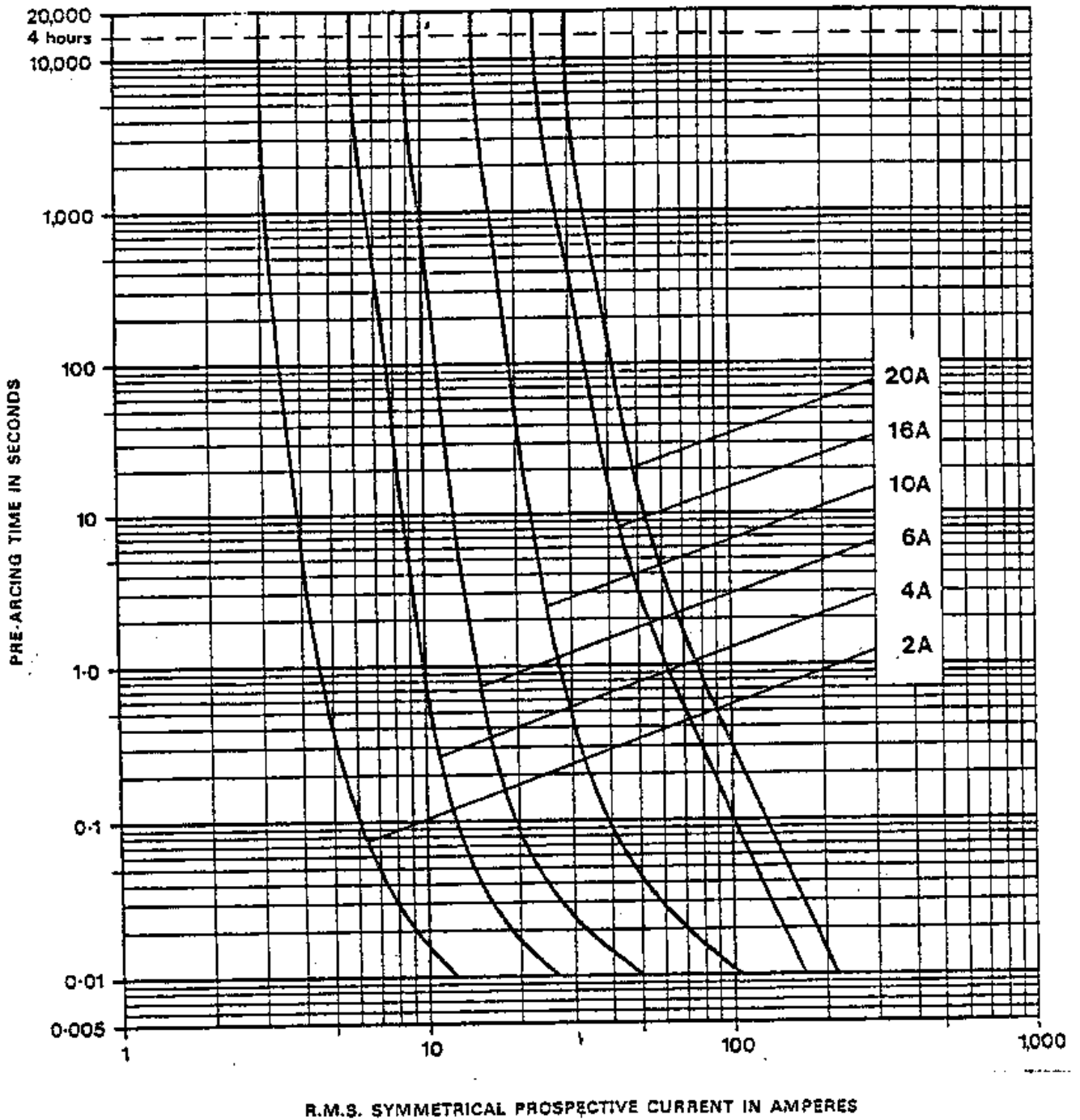
- (e) State **ONE** reason why thermistors would be used for motor protection in addition to thermal overloads and HRC fuses.

(1 mark)

(turn over)

Question 3

(a) The following graph shows the time/current characteristics of HRC fuses.



(turn over)

Question 3 continued

- (a) (i) Describe what happens in an electrical installation when a fault occurs and there is **correct discrimination** between protective devices. (1 mark)

- (ii) In an electrical installation a distribution switchboard is protected by 20A HRC fuse. A final subcircuit on the switchboard is protected by a 10A HRC fuse

Refer to the graph and explain how discrimination occurs when a 90A fault current occurs in the final subcircuit.

(3 marks)

- (iii) A 16A HRC fuse has a fusing factor (utilisation category) of 1.5. **Refer to the graph** and state:

(A) How long it will it take the 16A fuse to operate when the fusing current flows?

(2 marks)

(B) What level of fault current needs to flow to ensure the 16A fuse operates within 0.4 s?

(1 mark)

(turn over)

Question 3 continued

(b) The total clearance time of an HRC comprises the **pre-arcing time** and the **arcing time**.

(i) Define the term **pre-arcing time**.

(1 mark)

(ii) Define the term **arcing time**.

(1 mark)

(c) State the precaution that needs to be taken when an HRC fuse rated at AC 20, 550V is used for protection in a **d.c. final subcircuit**.

(1 mark)

(turn over)

Question 4

- (a) A single-phase, split-phase induction motor comprises a stator, a start winding, a centrifugal switch and a run winding.

The start winding and centrifugal switch form a closed circuit, the run winding is open-circuited. Explain why the motor does not rotate when it is switched on.

(5 marks)

- (b) The single-phase split-phase motor in a refrigerator is a sealed unit that incorporates only the start and run windings.

- (i) State how the start winding is disconnected after starting. (1 mark)

- (ii) At what percentage (%) of full-load speed does the start winding become disconnected? (1 mark)

(turn over)

Question 4 continued

- (c) State what would occur if a 230V, single-phase capacitor-start motor that was running suddenly experienced a 50% drop in speed due to mechanical overloading **and** the electrical protection failed to operate?

(1 mark)

- (d) (i) State **ONE** reason why a universal motor is generally used in conjunction with a gear train.

(1 mark)

- (ii) Describe what could occur if a universal motor **was not** used in conjunction with a gear train.

(1 mark)

- (iii) Describe how to reverse the direction of rotation of a universal motor.

(1 mark)

- (e) Describe how to reverse the direction of rotation of a single-phase capacitor-start motor.

(1 mark)

(turn over)

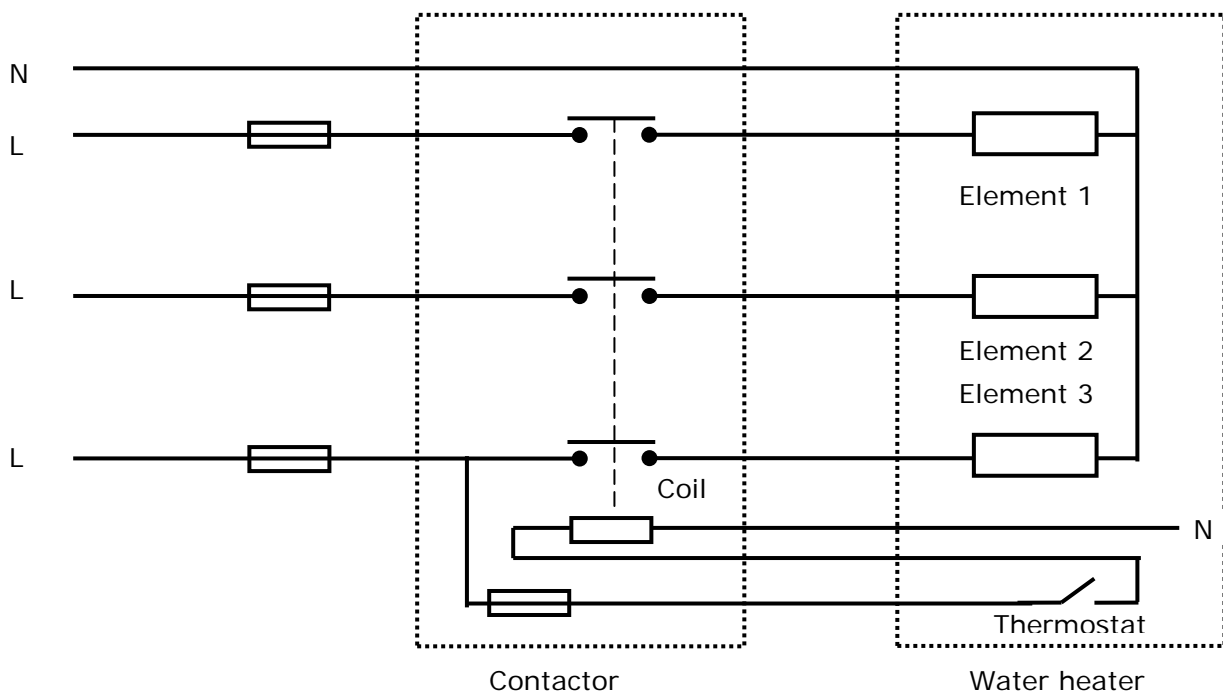
Question 5

Introduction

This is a circuit diagram of a three-phase electric hot-water cylinder with three 230V, 3 kW elements controlled by a contactor (the isolating switch is not shown). The HRC fuses are at the switchboard.

PVC cables in PVC flexible conduit connect the contactor to the cylinder.

The cylinder case and each element boss are connected to a protective earthing conductor.



The cylinder has been isolated at the isolating switch and a danger tag attached

A fault has occurred on the cylinder and the fuse protecting element 1 has blown. However, there is no fault on the circuit between the switchboard and the load side of the contactor.

Use the information in the introduction to this question to answer parts 5(a), 5(b) and 5(c).

(turn over)

Question 5 continued

- (a) Why did the cylinder continue to draw current (operate) with the fuse to element 1 blown?

(1 mark)

- (b) State the **TWO** possible causes of the fault that caused the fuse to blow that was protecting element 1.

(2 marks)

(1) _____

(2) _____

(turn over)

Question 5 continued

(c) For the faults stated in (b) describe how testing is carried to locate the faults. Include:

- The test instrument used
- The test voltage (if applicable)
- The expected test result for each of the faults stated in (b)

(7 marks)

(turn over)

Question 6

(a) Define the following lighting terms:

(i) Luminous intensity

(1 mark)

(ii) Luminous flux

(1 mark)

(iii) Luminous efficacy

(1 mark)

(iv) Colour rendering

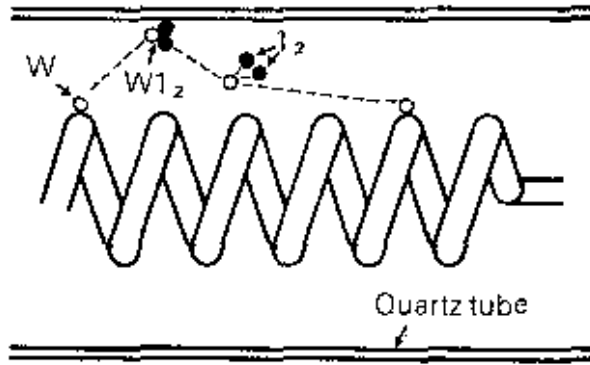
(1 mark)

(turn over)

Question 6 continued

- (b) The halogen cycle ensures that a halogen lamp maintains a constant initial output and colour temperature throughout the lamp's life.

The figure below represents the inside of a halogen lamp.



- (i) Describe how the **halogen cycle** operates within the halogen lamp. (3 marks)

(turn over)

Question 6 continued

- (ii) Explain why the halogen cycle ensures that a halogen lamp maintains a constant initial output and colour temperature. (2 marks)

- (c) State the effect on the operation of a discharge lamp if the ballast short-circuited while the lamp was operating and the control system was inoperative. (1 mark)

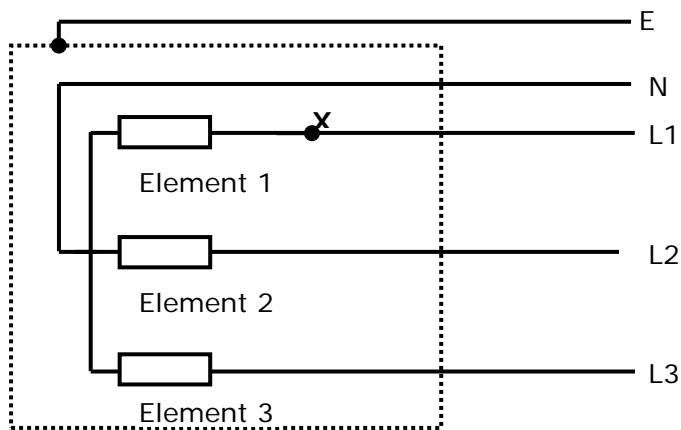
(turn over)

Question 7

Introduction

The figure below represents a 400V, three-phase commercial oven comprising three 6 kW single-phase elements.

Each phase is protected by a 40A HRC fuse with a fusing factor (gG Utilisation Category) of 1.5.



An earth fault of 6Ω has developed between L1 and the oven frame while the oven is operating. The fault occurred at point X.

The earth fault loop impedance is 0.38Ω .

Use the information in the introduction to this question to answer parts 7(a), 7(b), and 7(c)

(turn over)

Question 7 continued

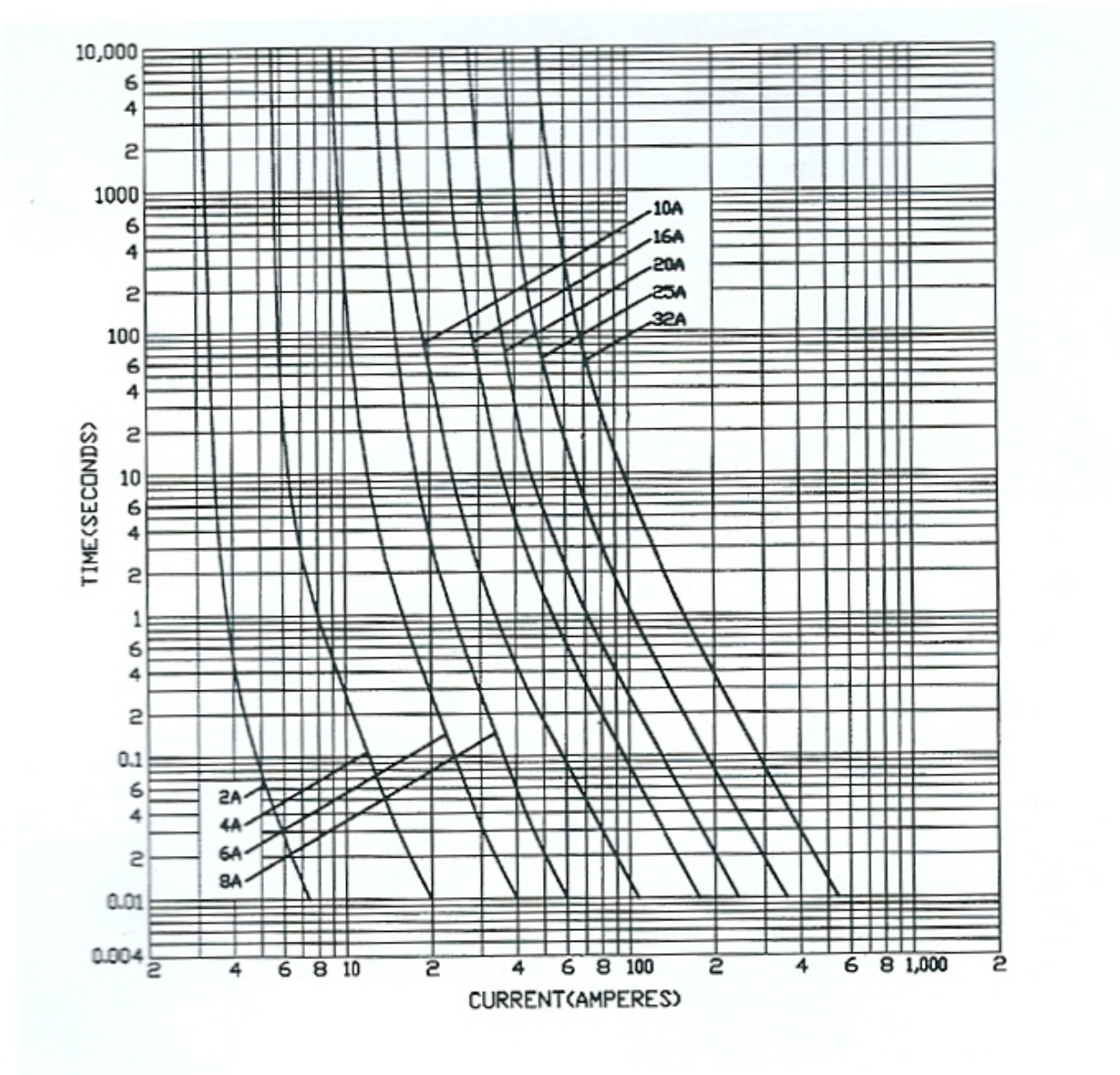
- (a) Calculate the total current that will flow in L1 under the fault conditions.
(6½ marks)

(turn over)

Question 7 continued

- (b) Refer to the following graph and determine how long it will take the 32A HRC fuse to operate with the fault current flowing.

(1 mark)



(turn over)

Question 7 continued

- (c) The protective earthing conductor resistance is 0.28Ω .

Use calculations to determine whether any touch voltage hazard exists to the operator of the oven.

(2½ marks)

(turn over)

Question 8

(a) Danger tags and out-of-service tags are designed to promote safety in the workplace.

(i) Give a brief description of circumstances when a Danger Tag is used. (1 mark)

(ii) Give a brief description of circumstances when an Out-of-Service Tag is used. (1 mark)

(iii) State **TWO** precautions to be taken when attaching a danger tag to an isolating switch. (2 marks)

(1)

(2)

(turn over)

Question 8 continued

- (b) (i) Define the term **switching off** as it relates to three-phase equipment.
(1 mark)

- (ii) Define the term **isolation** as it relates to three-phase equipment.
(2 marks)

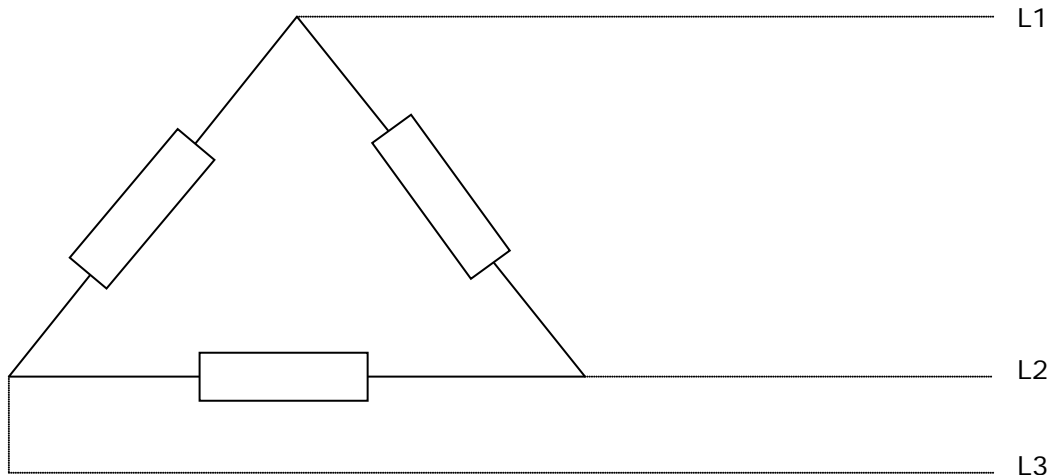
- (c) Describe how the **prove-test-prove** method of testing is carried out.
(3 marks)

(turn over)

Question 9

Introduction

The following diagram represents the three elements in a 400V, three-phase industrial kiln. Each element has a resistance of 17.77Ω .



Note: Voltage drop has no effect on the size of the cable because the route length is too short.

Use the information in the introduction to this question and the following tables to answer parts 9(a), 9(b), 9(c) and 9(d).

(turn over)

Question 9 continued

(a) Use calculations to determine the minimum size three-phase copper cable that can carry the kiln load current when the elements are in the delta configuration.

- The cable will be installed unenclosed (touching).
- The ambient air temperature is 30°C
- The conductor temperature is 75°C .

(4 marks)

(b) Calculate total **power** output of the kiln when the elements are in the delta configuration.

(2 marks)

(turn over)

Question 9 continued

- (c) State the minimum current rating of the HRC fuses used to protect the final subcircuit supplying the kiln when the elements are in the delta configuration.

(1 mark)

- (d) Calculate the difference in the power output of the kiln if the elements were connected in star.

(3 marks)

(turn over)

Question 9 continued

TABLE 10 CONTINUED

CURRENT-CARRYING CAPACITIES

CABLE TYPE: TWO-CORE SHEATHED
Cable with or without earth core, armoured or unarmoured, including neutral screened cables

INSULATION TYPE: THERMOPLASTIC

MAXIMUM CONDUCTOR TEMPERATURE: 75°C

REFERENCE AMBIENT TEMPERATURE: 30°C IN AIR, 15°C IN GROUND

14	15	16	17	18	19	20	21	22	23	24	25	26	27
Conduct or size	Current carrying capacity A												
	Thermal insulation								Buried direct		Underground wiring enclosure		
	Partially surrounded by thermal insulation, unenclosed		Partially surrounded by thermal insulation, in a wiring enclosure		Completely surrounded by thermal insulation, unenclosed		Completely surrounded by thermal insulation, in a wiring enclosure						
	mm ²	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	
											Solid/stranded	Flexible	
1	13	-	11	-	8	-	7	-	19	-	19	20	-
1.5	61	-	15	-	10	-	9	-	23	-	23	24	-
2.5	23	-	22	-	15	-	14	-	33	-	33	32	-
4	31	-	27	-	19	-	17	-	43	-	43	42	-
6	40	-	35	-	25	-	23	-	55	-	55	53	-
10	55	-	48	-	34	-	30	-	73	-	73	72	-
16	73	56	62	48	46	35	39	30	125	97	95	94	73
25	97	75	82	64	60	47	51	40	162	125	123	119	96
35	120	92	103	80	74	58	64	49	196	152	150	146	117
50	145	113	122	95	-	-	-	-	232	179	178	179	139
70	184	143	155	120	-	-	-	-	285	221	222	222	173
95	226	176	186	145	-	-	-	-	342	265	267	260	208
120	262	204	219	171	-	-	-	-	391	304	310	305	242
150	300	233	247	192	-	-	-	-	438	340	349	344	271
185	344	268	285	222	-	-	-	-	494	385	399	388	311
240	407	318	332	260	-	-	-	-	572	447	463	461	362
300	466	366	388	303	-	-	-	-	645	506	531	519	417
400	537	425	440	349	-	-	-	-	729	579	603	616	477
500	609	489	512	410	-	-	-	-	815	655	691	692	554

(turn over)

Question 9 continued

TABLE 13

CURRENT-CARRYING CAPACITIES

CABLE TYPE: **THREE-CORE AND FOUR-CORE**
 Cable with or without earth core, armoured or unarmoured, including neutral screened cables

INSULATION TYPE: **THERMOPLASTIC**

MAXIMUM CONDUCTOR TEMPERATURE: **75°C**

REFERENCE AMBIENT TEMPERATURE: **30°C IN AIR, 15°C IN GROUND**

1	2	3	4	5	6	7	8	9	10	11	12	13
Conductor size	Current carrying capacity A											
	Unenclosed									Enclosed		
	Spaced			Touching			Exposed to sun			Wiring enclosure in air		
	Cu		Al	Cu		Al	Cu		Al	Cu		Al
mm ²	Solid/stranded	Flexible		Solid/stranded	Flexible		Solid/stranded	Flexible		Solid/stranded	Flexible	
1	15	15	-	14	15	-	10	11	-	13	13	-
1.5	18	19	-	17	18	-	14	14	-	16	16	-
2.5	26	25	-	25	24	-	19	18	-	23	22	-
4	35	34	-	33	32	-	26	25	-	29	27	-
6	46	43	-	42	41	-	33	32	-	38	36	-
10	62	62	-	58	58	-	44	43	-	50	49	-
16	82	81	64	78	76	60	58	57	46	66	65	51
25	111	107	86	104	101	81	76	74	59	87	83	67
35	137	133	106	128	125	99	93	91	73	107	105	83
50	166	169	129	156	157	121	113	114	88	128	128	99
70	211	211	163	196	197	153	140	140	109	162	162	127
95	260	253	202	243	236	188	171	165	132	202	196	156
120	302	299	235	282	278	219	196	193	153	230	227	179
150	345	343	268	321	319	250	221	219	172	260	261	202
185	397	390	310	369	363	288	251	245	196	300	293	235
240	470	464	368	437	431	343	292	286	228	360	352	283
300	538	529	424	499	490	393	328	321	259	-	-	-
400	620	626	495	575	579	458	372	372	296	-	-	-
500	702	715	568	651	661	526	414	416	335	-	-	-

(turn over)

Question 9 continued

TABLE 13 CONTINUED

CURRENT-CARRYING CAPACITIES

CABLE TYPE: **THREE-CORE AND FOUR-CORE**
 Cable with or without earth core, armoured or unarmoured, including neutral screened cables

INSULATION TYPE **THERMOPLASTIC**

MAXIMUM CONDUCTOR TEMPERATURE **75°C**

REFERENCE AMBIENT TEMPERATURE **30°C IN AIR, 15°C IN GROUND**

14	15	16	17	18	19	20	21	22	23	24	25	26	27
Conductor size	Current carrying capacity A												
	Thermal insulation								Buried direct		Underground wiring enclosure		
	Partially surrounded by thermal insulation, unenclosed		Partially surrounded by thermal insulation, in a wiring enclosure		Completely surrounded by thermal insulation, unenclosed		Completely surrounded by thermal insulation, in a wiring enclosure		Cu	Al	Cu		Al
	mm ²	Cu	Al	Cu	Al	Cu	Al	Cu			Al	Solid/stranded	
1	10	-	10	-	7	-	6	-	15	-	15	17	-
1.5	14	-	13	-	9	-	8	-	20	-	20	20	-
2.5	18	-	18	-	13	-	11	-	28	-	28	26	-
4	26	-	23	-	17	-	15	-	36	-	36	35	-
6	34	-	30	-	22	-	18	-	46	-	46	44	-
10	47	-	40	-	29	-	25	-	61	-	61	59	-
16	62	48	54	41	39	30	33	26	106	83	80	78	62
25	83	65	68	54	52	40	43	33	138	107	103	100	80
35	103	79	86	66	64	49	54	41	165	129	125	123	98
50	124	97	101	79	-	-	-	-	196	152	150	151	116
70	157	122	130	100	-	-	-	-	241	187	187	186	145
95	194	150	162	125	-	-	-	-	289	224	229	221	177
120	226	176	185	144	-	-	-	-	330	256	261	255	202
150	258	200	207	162	-	-	-	-	370	287	293	292	228
185	295	231	241	188	-	-	-	-	417	326	334	326	261
240	350	274	288	226	-	-	-	-	482	378	395	386	309
300	-	-	-	-	-	-	-	-	542	427	444	433	350
400	-	-	-	-	-	-	-	-	613	488	515	514	411
500	-	-	-	-	-	-	-	-	682	551	574	575	464

(turn over)

Question 9 continued

Table 27(1)

VARIANCE: AIR AND CONCRETE SLAB AMBIENT TEMPERATURES

INSTALLATION CONDITIONS CABLES IN AIR OR HEATED CONCRETE SLAB

1	2	3	4	5	6	7	8	9	10	11
Conductor temperature °C	Rating Factor									
	Air and concrete slab ambient temperature									
	15	20	25	30	35	40	45	50	55	60
150	1.07	1.05	1.03	1.00	0.98	0.96	0.94	0.91	0.89	0.87
110	1.08	1.06	1.03	1.00	0.97	0.93	0.90	0.87	0.83	0.79
90	1.15	1.09	1.05	1.00	0.95	0.91	0.85	0.80	0.74	0.66
80	1.17	1.12	1.06	1.00	0.95	0.89	0.82	0.75	0.68	0.59
75	1.18	1.12	1.06	1.00	0.94	0.88	0.80	0.72	0.63	0.53

Table 27(2)

VARIANCE: SOIL AMBIENT TEMPERATURES

INSTALLATION CONDITIONS CABLES BURIED DIRECT IN GROUND OR IN UNDERGROUND WIRING ENCLOSURES

1	2	3	4	5	6	7	8
Conductor temperature °C	Rating Factor						
	Soil ambient temperature						
	10	15	20	25	30	35	40
110	1.02	1.00	0.97	0.94	0.92	0.89	0.86
90	1.04	1.00	0.96	0.93	0.91	0.87	0.83
80	1.04	1.00	0.95	0.92	0.88	0.83	0.78
75	1.04	1.00	0.95	0.91	0.86	0.81	0.75

(turn over)

Question 9 continued

Table 42

THREE-PHASE VOLTAGE DROP (V_c) at 50 Hz

CABLE TYPE: MULTICORE WITH CIRCULAR COPPER CONDUCTORS

Conductor size mm ²	Three-phase voltage drop (V_c) at 50 Hz, mV/A.m									
	Conductor temperature, °C									
	45		60		75		90		110	
	Max.	0.8 p.f.	Max.	0.8 p.f.	Max.	0.8 p.f.	Max.	0.8 p.f.	Max.	0.8 p.f.
1	40.3	-	42.5	-	44.7	-	46.8	-	49.7	-
1.5	25.9	-	27.3	-	28.6	-	30.0	-	31.9	-
2.5	14.1	-	14.9	-	15.6	-	16.4	-	17.4	-
4	8.77	-	9.24	-	9.71	-	10.2	-	10.8	-
6	5.86	-	6.18	-	6.49	-	6.80	-	7.22	-
10	3.49	-	3.67	-	3.86	-	4.05	-	4.29	-
16	2.19	-	2.31	-	2.43	-	2.55	-	2.70	-
25	1.39	-	1.47	-	1.54	-	1.61	-	1.71	-
35	1.01	-	1.06	-	1.11	-	1.17	-	1.24	-
50	0.751	-	0.790	-	0.829	-	0.868	-	0.920	-
70	0.530	-	0.556	-	0.583	-	0.609	-	0.645	-
95	0.394	-	0.413	-	0.431	-	0.450	-	0.475	-
120	0.323	-	0.337	-	0.351	-	0.366	-	0.385	-
150	0.274	-	0.285	-	0.296	-	0.307	-	0.322	-
185	0.234	-	0.242	-	0.251	-	0.259	-	0.271	-
240	0.198	0.198	0.204	0.204	0.210	0.210	0.216	0.216	0.224	-
300	0.178	0.175	0.182	0.180	0.186	0.185	0.190	0.189	0.196	0.196
400	0.162	0.157	0.165	0.160	0.168	0.164	0.171	0.167	0.175	0.172
500	0.152	0.143	0.154	0.146	0.156	0.148	0.158	0.151	0.160	0.155

Note: To convert to single-phase values multiply the three-phase value by 1.155

Table 45

THREE-PHASE VOLTAGE DROP (V_c) at 50 Hz

CABLE TYPE: MULTICORE WITH CIRCULAR ALUMINIUM CONDUCTORS

Conductor size mm ²	Three-phase voltage drop (V_c) at 50 Hz, mV/A.m									
	Conductor temperature, °C									
	45		60		75		90		110	
	Max.	0.8 p.f.	Max.	0.8 p.f.	Max.	0.8 p.f.	Max.	0.8 p.f.	Max.	0.8 p.f.
16	3.64	-	3.84	-	4.04	-	4.11	-	4.24	-
25	2.29	-	2.42	-	2.54	-	2.59	-	2.67	-
35	1.66	-	1.75	-	1.84	-	1.87	-	1.93	-
50	1.23	-	1.30	-	1.36	-	1.39	-	1.43	-
70	0.856	-	0.902	-	0.948	-	0.966	-	0.993	-
95	0.626	-	0.659	-	0.691	-	0.706	-	0.723	-
120	0.501	-	0.527	-	0.552	-	0.565	-	0.577	-
150	0.416	-	0.436	-	0.457	-	0.468	-	0.476	-
185	0.341	-	0.357	-	0.373	-	-	-	0.388	-
240	0.274	-	0.285	-	0.297	-	-	-	0.307	-
300	0.233	-	0.242	-	0.251	-	-	-	0.258	-
400	0.200	0.200	0.206	0.206	0.212	-	-	-	0.216	-
500	0.178	0.176	0.182	0.181	0.186	0.185	-	-	0.189	0.189

Note: To convert to single-phase values multiply the three-phase value by 1.155

For Candidate's Use

In the box, write the number of **EXTRA** sheets you have used. Write **NIL** if you have not used any

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Questions Answered	Marks	
1		
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TOTAL		