Electrical Systems Safety

MODULE RESOURCE MANUAL

MANUFACTURING AND ENGINEERING DIVISION

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING

TAFE NSW

M & E

NUE505A

TRAINING STANDARDS

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ELECTRICAL SYSTEMS SAFETY

NUE505A

FEEDBACK

We value your opinion and welcome suggestions on how we could improve this resource manual. Keep in mind that the manual is intended to help students learn and is not a text book.

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Contents

Introduction

This resource manual contains learning exercises, review questions and sample assessment instruments. It is designed to assist students to prepare for the assessment outcomes and purpose described in the national module descriptor *NUE505A Electrical Systems Safety* and is an example of the depth and breadth of learning expected.

The topics listed in the content are arranged in the preferred sequence. It is recognised that this is not the only sequence in which the material could be learnt.

General references of this module

The following textbooks are recommended for this module:

Principal reference

To help you with this module, the following resource material will be useful:

- *AS/NZS 3000:2000 Wiring Rules,* Standards Australia.
- *AS/NZS 3008.1.1:1998 Electrical Installations - Selection of Cables,* Standards Australia.
- *AS/NZS 3017:2001 Electrical Installations - Testing and Inspection Guidelines,* Standards Australia.
- *HB300-2001, Electrical Installations,* Standards Australia.
- Pethbridge K. and Neeson I., *Electrical Wiring Practice*, Vols 1& 2, 6th Edition, McGraw-Hill Book Company, Roseville, NSW, 2002.
- Jenneson J., *Electrical Principles for the Electrical Trades*, 5th Edition, McGraw-Hill Book Company, Roseville, NSW, 2003.
- Local supply authorities service rules & installation publications.

Minimum equipment requirements

To enable you to complete this module you will need access to:

- pens, pencils, ruler, etc.
- calculator
- writing paper.

Notes

1. Working Safely

What this topic covers

This topic provides exercises in knowledge and skills required to work safely within an electrical environment as preparation for the Electrical Systems Safety assessment. It covers part of the critical knowledge and skills for ensuring that safe working practices are followed.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- testing circuits for supply
- safe isolating procedures
- lockout procedures
- assessing the risk of injury or damage in a given work environment
- implementing measures to alternate or reduce the identified risks to an acceptable level.
- the safe working procedure when using tools and plant
- isolating, tag and testing electrical supplies effectively.

Where you will find information

The following references will help you in completing the exercises and review questions in this topic.

- Pethbridge K. and Neeson I., *Electrical Wiring Practice K.*, 6th Edition, Vol. 2, McGraw-Hill, Sydney, Chapter 2.
- *HB300-2001, Electrical Installations*, Part 4, Standards Australia
- *AS/NZS 3000:2000 Wiring Rules,* Standards Australia.

Student exercise 1.1 Testing "dead" circuits

Your supervisor instructed you to carry out repairs to an electric hot water service in a large warehouse.

The hot water service is supplied by its own final sub-circuit and you have been told that the circuit is 'dead' because the fuse has been removed at the remote main switchboard.

What safety measures, if any, would you carry out before proceeding with the work?

Student exercise 1.2 Testing "live" circuits

You are to disconnect a faulty single-phase 230 V, 4.6 kW electric off peak hot water system from its final sub-circuit conductors, which is located in a cupboard in a single storey house.

You have removed the terminal box cover and are about to test the water heater conductors for supply.

Briefly explain the sequence of testing for 'live' when using a voltage tester.

Student exercise 1.3 Isolating procedures - single phase circuit

Your supervisor has instructed you to relocate a single-phase 230 V hot plate unit and its associated wiring in the kitchen of a house. You are to be assisted by a first year apprentice.

The hotplate unit is supplied by its own final sub-circuit and the circuit breaker protecting the hotplate is located on the main switchboard outside.

The final sub-circuit will remain connected to the load side of the protective devices during the relocation.

Describe in detail the procedure you would undertake to ensure that the job is carried out in a safe manner.

Student exercise 1.4 Isolating procedures - three-phase circuit

You have being instructed by your foreman to relocate a 400 volt three phase induction motor in a factory. An isolating switch is adjacent to the motor and is to remain in close proximity to it after it has been relocated. The HRC fuses protecting the motor are located on a distribution board in another area of the factory and is out of your view.

Describe the procedures that you would undertake to ensure that the job is carried out safely.

Review questions

These questions will help you revise what you have learnt in this topic.

1. What checks should you make on a set of series test lamps before using them?

2. What typical ratings do the lamps in a set of series test lamps have?

3. Identify one advantage a voltage probe has over a set of series test lamps.

4. Before working on electrical equipment you should isolate the supply to the equipment and then:

5. What magnitude of current is enough to stop the heart?

6. What factors affect the severity of electric shock?

7. What is the purpose of a 'danger tag'?

8. When using a voltage presence indicator it is important to connect the first lead to neutral or earth. Why is this?

9. Name three types of voltage presence indicators.

2. Protection for safety

What this topic covers

This topic provides exercises in the 'Protection for Safety' requirements of AS/NZS 3000:2000 in preparation for the Electrical Systems Safety assessment. It covers part of the critical knowledge and skills for ensuring that protective devices in an electrical installation will operate as intended.

What you are expected to be able to do

Demonstrate knowledge of the acceptable methods for protecting persons and livestock against injury and property against damage from:

- contact with live parts of an electrical installation
- contact with exposed conductive parts which may become live under fault condition
- thermal effects of current in normal service
- overcurrent and fault current, and
- unwanted and overvoltage.

Where you will find information

The following references will help you in completing the exercises and review questions in this topic.

- *AS/NZS 3000:2000 Wiring rules,* Sections 1 and 2, Standards Australia.
- *HB300, Electrical Installations*, Part 2, Standards Australia.
- Pethebridge K. and Neeson I., *Electrical Wiring Practice*, 6th Ed., Vol. 2, McGraw-Hill, Sydney, Chapters 12, 13 and 14.

Student exercise 2.1 Protection against direct contact

Familiarise yourself with *Clause 1.7.3* before attempting this exercise.

1. What are the requirements where insulation is the method for protecting against direct contact with live parts?

2. What degree of protection is needed where barriers provide the method for protecting against direct contact with live parts?

3. What are the constructional requirements where barriers provide the method for protecting against direct contact with live parts?

4. What are the requirements where the method for protecting against direct contact with live parts is the provision of obstacles?

5. What are the requirements where placing out of reach provides the method for protecting against direct contact with live parts?

Student exercise 2.2 Protection against indirect contact

It is necessary to protect persons and livestock against the dangers arising from contact with exposed conductive parts that may become live under fault conditions.

Familiarise yourself with *Clause 1.7.4* before attempting this exercise.

1. What is the intention of measures for protecting against indirect contact with live parts?

Suitable methods of protecting against indirect contact with live parts include:

- Automatic disconnection of supply
- Use of Class II equipment or equivalent insulation
- Electrical separation

2. What is the purpose of automatic disconnection of supply when protecting against indirect contact with live parts?

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It is possible to achieve this protective measure through:

- Provision of a system of earthing where exposed conductive parts connect to a protective earthing conductor
- Disconnection of the fault by an over-current protective device or an RCD

3. If a fault exists between a live part and exposed conductive part, the protective device must automatically disconnect the supply where the touch voltage exceeds what limits?

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4. For fault loop impedance, the product of what two values must not exceed the nominal a.c. rms voltage to earth?

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5. For a 230-volt final subcircuit comprising socket outlets, hand-held Class I equipment or other portable equipment, what is the maximum disconnection time for automatic disconnection devices?

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6. For a 230 volt final subcircuit supplying fixed equipment or submain, what is the maximum disconnection time for automatic disconnection devices?

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7. It is possible to reduce the fault-loop impedance by bonding extraneous conductive parts to the protective earthing system. What is the name given to this?

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8. What means are suitable for providing protection against dangerous voltages occurring on accessible conductive parts of electrical equipment in the event of a fault in the basic insulation?

9. What measures are not considered to provide a suitable insulation covering?

10. Briefly outline the measures for providing electrical separation.

Student exercise 2.3 Protection against thermal effects

It is necessary to arrange installations so that there is no risk of ignition of flammable materials due to high temperature or electric arc in normal operation. Furthermore, there should be no risk of persons or livestock suffering burns during the normal operation of electrical equipment.

Familiarise yourself with *Clause 1.7.6* before attempting this exercise.

1. What means are suitable for providing protection from the risk of ignition of flammable materials in normal service?

2. What means are suitable for providing protection from the risk of burns in normal service?

Student exercise 2.4 Protection against voltages and currents

It is necessary to arrange installations to minimise the effects of unwanted voltages, over-current, fault current and over-voltage.

Familiarise yourself with *Clauses 1.7.7, 1.7.8, 1.7.9 and 1.7.10* before attempting this exercise.

1. What means are suitable for protecting an installation from the effect of unwanted voltages?

2. What means are suitable for protecting an installation from the effect of over-current?

3. What means are suitable for protecting an installation from the effect of fault currents?

4. What means are suitable for protecting an installation from the effect of over voltage?

Review questions

These questions will help you revise what you have learnt in this topic.

1. What are four methods for protecting against direct contact with live parts?

   AS/NZS 3000 Reference: ______________________

2. What are the requirements when insulation surrounds live parts to protect against direct contact?

   AS/NZS 3000 Reference: ______________________

3. Where a barrier or enclosure provides protection against direct contact with live parts, what degree of protection must the barrier or enclosure provide?

   AS/NZS 3000 Reference: ______________________

4. What are the requirements to prevent direct contact with live parts, where electrical equipment requires a large opening to facilitate lamp replacement?

   AS/NZS 3000 Reference: ______________________

5. What conditions must be satisfied before being able to remove a barrier that prevents contact with live parts of electrical equipment?

   AS/NZS 3000 Reference: ______________________

6. Simultaneously accessible parts at different voltages must not be within arm's reach. What does this mean?

   AS/NZS 3000 Reference: ______________________

7. What methods are suitable for protecting against indirect contact with live electrical parts?

   AS/NZS 3000 Reference: ______________________

8. Within what time must an over-current device automatically disconnect a final subcircuit supplying 10 A socket outlets?

   AS/NZS 3000 Reference: ______________________

9. What are suitable methods for protecting against the risk of flammable materials igniting in normal service?

   AS/NZS 3000 Reference: ______________________

10. What are suitable methods for protecting circuits from over-voltage?

    AS/NZS 3000 Reference: ______________________

3. Earthing System

What this topic covers

This topic provides exercises in earthing systems and the AS/NZS 3000:2000 requirements for the multiple earthed neutral (MEN) system in preparation for the Electrical Systems Safety Assessment. It covers part of the critical knowledge and skills to ensure correct earthing of electrical installations.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- the main features and components of the multiple earthed neutral system, and
- acceptable earthing arrangements for the multiple earthed neutral system.

Where you will find information

The following references will help you in completing the exercises and review questions in this topic.

- *AS/NZS 3000:2000 Wiring rules*, Sections 1 and 5, Standards Australia.
- *HB300, Electrical Installations*, Part 2.
- Pethebridge K. and Neeson I., *Electrical Wiring Practice*, 6th Ed., Vol.2, McGraw-Hill, Sydney, Chapter 12.

Student exercise 3.1 Components of the multiple earthed neutral system

Revise clauses 1.4.40, 1.4.41, 1.4.49 and 1.4.54 and Section 5 of the Wiring Rules before attempting this exercise.

1. What does the term earthed mean?

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AS/NZS 3000 Reference: ____________________

2. What does the term equipotential bonding mean?

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AS/NZS 3000 Reference: ____________________

3. What does the term protective earthing conductor mean?

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AS/NZS 3000 Reference: ____________________

4. What is the maximum earth resistance for a lighting circuit?

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AS/NZS 3000 Reference: ____________________

5. What is the maximum size for a copper earthing conductor?

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AS/NZS 3000 Reference: ____________________

6. An installation has 185 mm^2 copper active conductors in the consumers mains. What size of earthing conductor should be used for the main earthing conductor?

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AS/NZS 3000 Reference: ____________________

7. At what point in a run of steel conduit should it be connected to the earthing system?

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AS/NZS 3000 Reference: ____________________

8. What is the recommended minimum wall thickness of a driven pipe earth electrode?

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AS/NZS 3000 Reference: ____________________

9. Explain the difference between protective earth and functional earth and give examples of each.

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AS/NZS 3000 Reference: ____________________

Student exercise 3.2 Earthing arrangements

Revise Section 5 of the Wiring Rules and in particular Clause 5.6.7 before attempting this exercise.

1. In the electrical installation represented in Figure 3.1 show an acceptable arrangement of earthing by drawing the necessary protective earthing and equipotential bonding conductors and writing on each conductor the compliant Clause No.

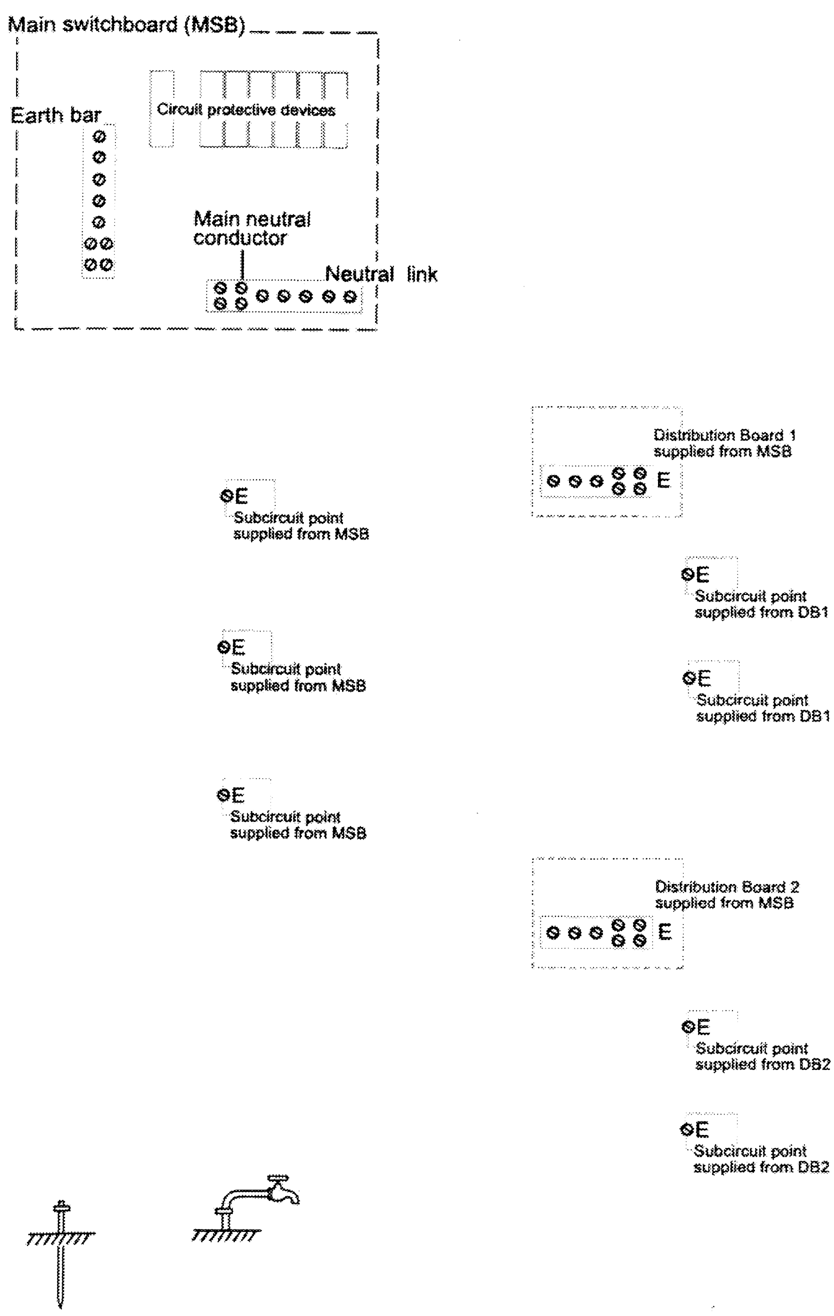

Figure 3.1 Earthing arrangements 1

2. In the electrical installation represented in Figure 3.2 show an acceptable arrangement of earthing by drawing the necessary protective earthing and equipotential bonding conductors and writing on each conductor the compliant Clause No.

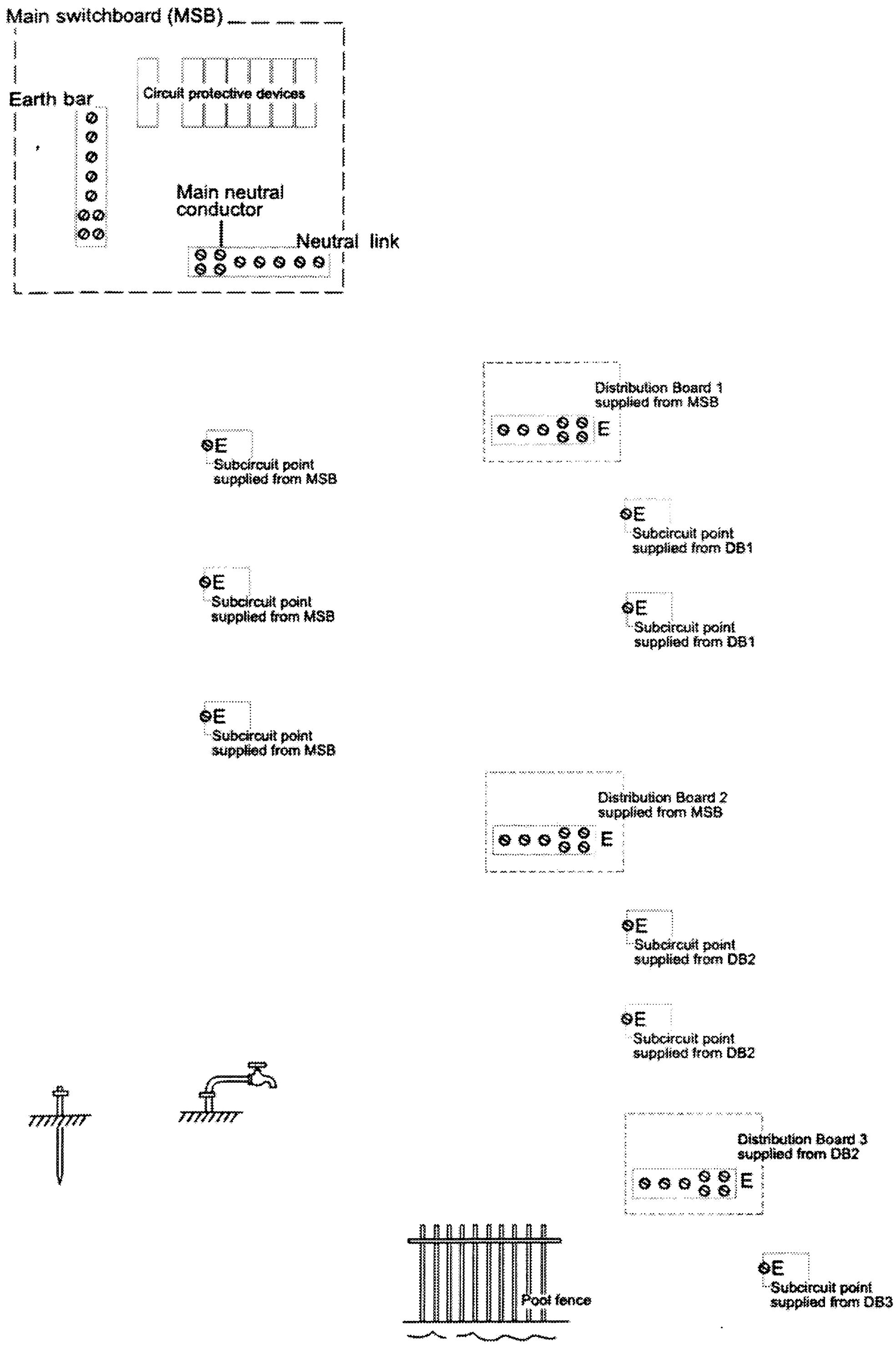

Figure 3.2 Earthing arrangements 2

3. In the electrical installation represented in Figure 3.3 outbuilding 3 is to be supplied via outbuilding 2 and both outbuilding are to have separate MEN installations. Outbuilding 1 does not have a separate MEN installation.

Show an acceptable arrangement of supply and earthing by drawing the supply and protective earthing conductors and writing on each conductor the compliant Clause No.

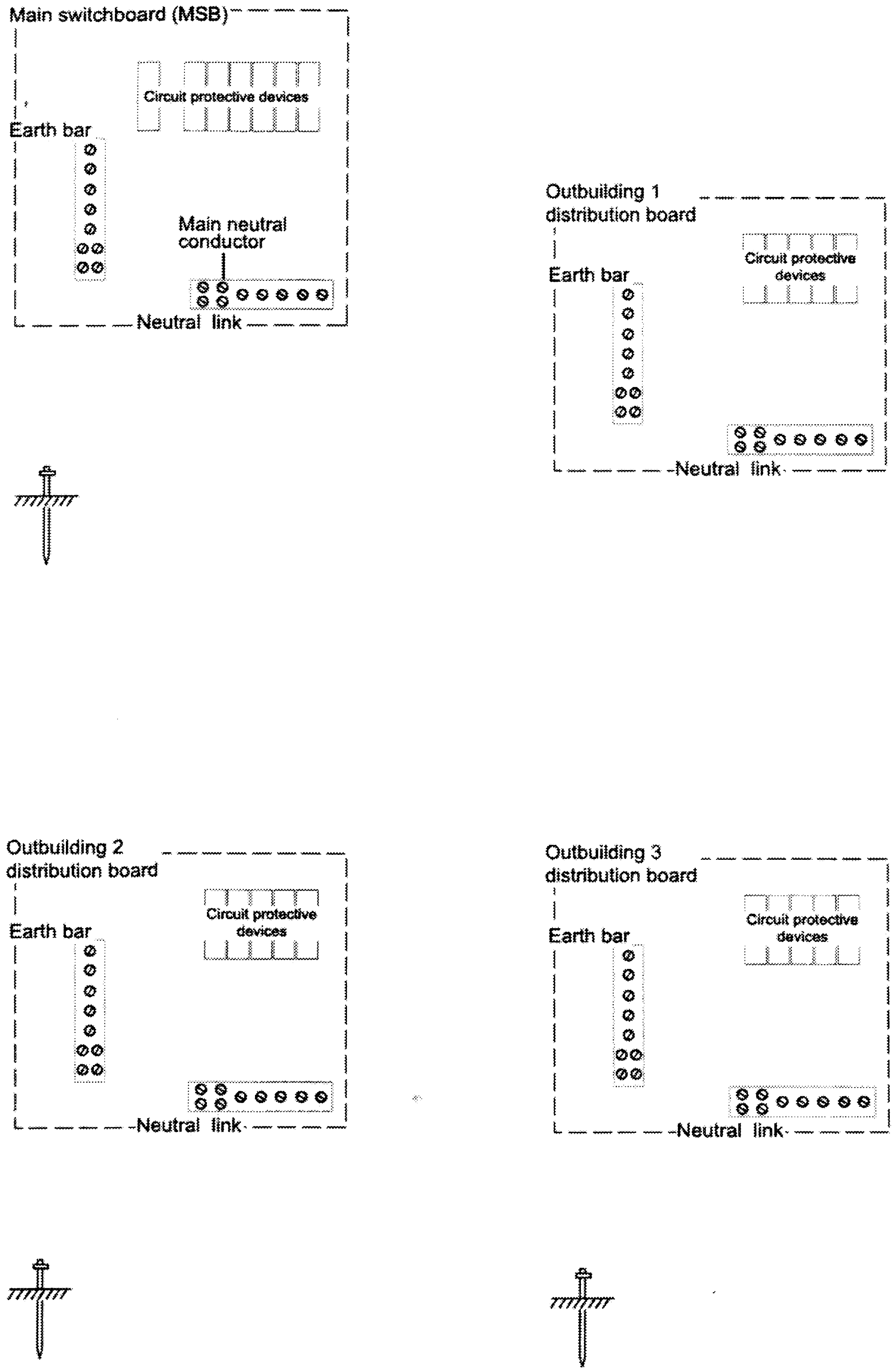

Figure 3.3 Earthing outbuildings

Review questions

These questions will help you revise what you have learnt in this topic.

1. The minimum size for the main earth conductor for a main switchboard having single phase 35 mm^2 SDI copper consumers mains having two effective layers of insulation that continue into the service fuse is:

   (A) 4 mm^2

   (B) 6 mm^2

   (C) 10 mm^2

   (D) equal to the cross-sectional area of the neutral conductor.

   AS/NZS 3000 Reference: ______________________

2. The minimum size earth conductor incorporated in a multi-core flexible cord is:

   (A) 0.5 mm^2

   (B) 1.0 mm^2

   (C) 2.5 mm^2

   (D) not less than largest associated active conductor.

   AS/NZS 3000 Reference: ______________________

3. The minimum size earth conductor incorporated in a multi-core cable is:

   (A) 0.5 mm^2

   (B) 1.0 mm^2

   (C) 2.5 mm^2

   (D) not specified in AS/NZS 3000:2000.

   AS/NZS 3000 Reference: ______________________

4. The maximum size of copper earth conductor need not be greater than:

   (A) 100 mm^2

   (B) 120 mm^2

   (C) 200 mm^2

   (D) not specified in AS/NZS 3000:2000.

   AS/NZS 3000 Reference: ______________________

5. The maximum specified resistance for the main earthing conductor is:

   (A) 0.5 Ω

   (B) 1.0 Ω

   (C) 2.0 Ω

   (D) large enough to allow the operation of the circuit protective device.

   AS/NZS 3000 Reference: ______________________

Review questions

6. With regards to protection against indirect contact, touch voltage is:
   (A) the difference of potential between conductors and earth
   (B) the difference of potential between simultaneously accessible parts
   (C) the supply voltage
   (D) 80% of the supply voltage.

   AS/NZS 3000 Reference: ______________________

7. It is not necessary to earth:
   (A) exposed conductive parts of a metallic wiring enclosure
   (B) exposed conductive parts of equipment supplied by flexible cord
   (C) equipment complying with AS/NZS 3100 for double insulation
   (D) transformers supplying ELV lighting systems.

   AS/NZS 3000 Reference: ______________________

8. Outbuilding (detached portion) of an electrical installation:
   (A) shall have more than one MEN connection
   (B) may be supplied via any number of distribution boards in the outbuilding
   (C) shall have the supply neutral conductor connected in parallel with a bonding conductor
   (D) may be earthed by a separate MEN installation.

   AS/NZS 3000 Reference: ______________________

9. What feature distinguishes the MEN system of earthing from the direct earthing system?

10. What advantage does the MEN system have over the direct earthing system?

11. Calculate the touch voltage for a single-phase final subcircuit having 4.0 mm^2 active conductor having a per unit impedance of 1.0 Ω and a 2.5 mm^2 earthing conductor having a per unit impedance of 2.4 Ω where the operating voltage of the installation is 230 V.

4. Protection Methods and Devices

What this topic covers

This topic provides exercises in the requirements of AS/NZS 3000:2000 to protect persons and livestock from injury and property from damage in preparation for the Electrical Systems Safely assessment. It covers part of the critical knowledge and skills needed to select appropriate electrical equipment and to ensure that in an electrical installation, protective devices will operate as intended.

What you are expected to be able to do

Demonstrate knowledge and skills related to the:

- operating principles of fuses, circuit breakers and residual current devices, and
- characteristics of fuses, circuit breakers and residual current devices in determining their suitability for particular installation conditions
- arrangements for protection by electrical separation, protected extra-low voltage (PELV) and separated extra-low voltage (SELV).

Where you will find information

The following references will help you in completing the exercises and review questions in this topic.

- *AS/NZS 3000:2000 Wiring rules,* Sections 1 and 5, Standards Australia.
- *HB300, Electrical Installations,* Part 2, Standards Australia.
- Pethebridge K. and Neeson I., *Electrical Wiring Practice*, 6th Ed., Vol.2, McGraw-Hill, Sydney, Chapter 13.

Student exercise 4.1 HRC Fuse construction

The device shown in Figure 4.1 is a HRC fuse cartridge. Name and explain the function of the components indicated on the fuse shown.

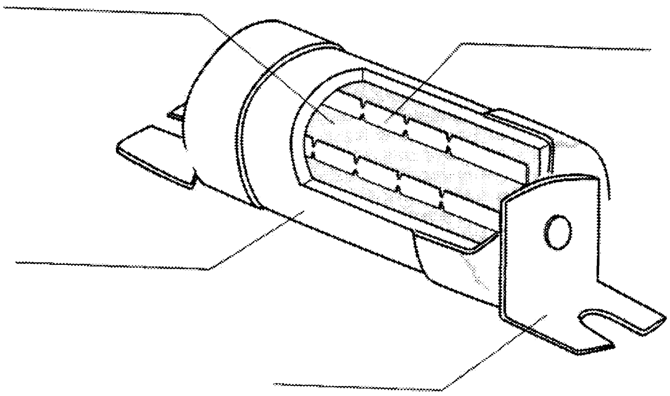

Figure 4.1

Student exercise 4.2 Time current characteristics

From the time-current characteristics shown in Figure 4.2, how long will it take the following fuses to 'blow'.

(a) 2 A - 5A overload

(b) 10 A - 100% overload

(c) 32 A - 600% overload

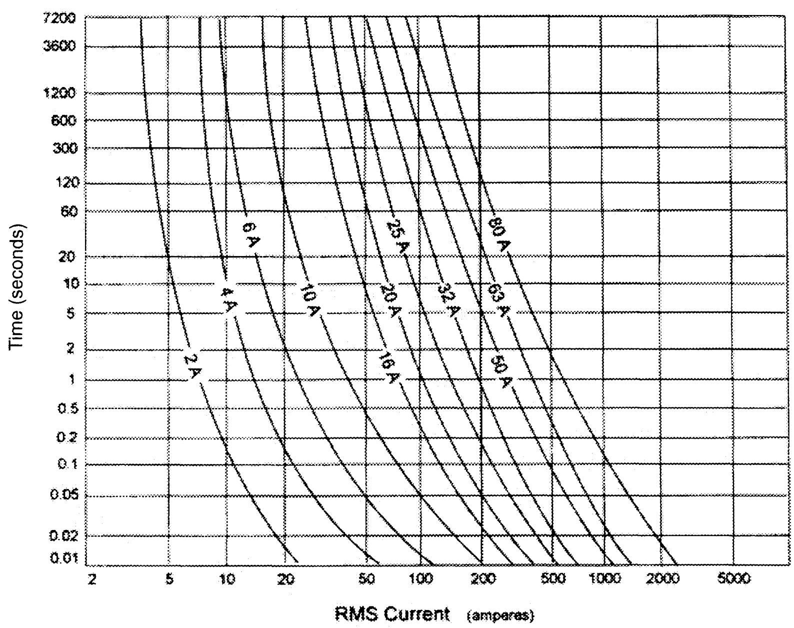

Figure 4.2

Student exercise 4.3 Circuit breaker construction

Name and explain the function of the components indicated on the circuit breaker shown in Figure 4.3.

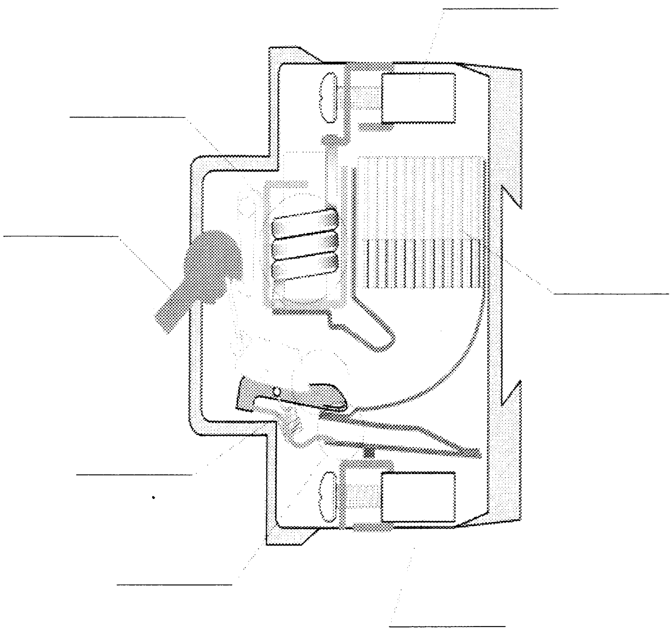

Figure 4.3

Student exercise 4.4 Circuit breaker characteristics

From the time-current characteristics shown in Figure 4.4, how long will it take the following circuit breakers to trip.

(a) 16 A circuit breaker if circuit current is 32 A.

(b) 32 A circuit breaker if circuit current is 50 A.

(c) 50 A circuit breaker on 150% overload

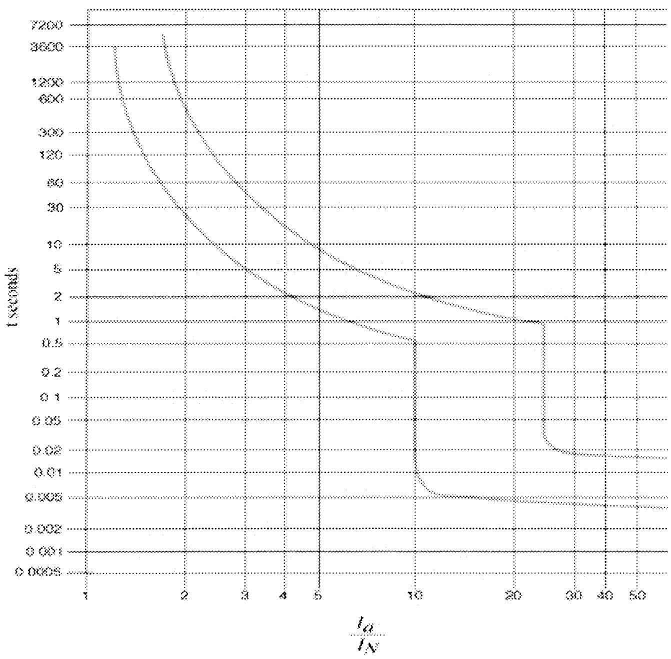

Figure 4.4

Student exercise 4.5 Arrangement of RCD circuits

1. The equipment shown in Figure 4.5 is for a switchboard in a domestic installation. Show on the diagram the necessary Active, Neutral and Earth connections for the following:
   - Circuit 1 22 lighting points
   - Circuit 2 12 double socket outlets
   - Circuit 3 11 double socket outlets

A four-pole RCD protects both power circuits and a two-pole RCD protects the lighting circuit.

Arrangement of the circuits places them partially surrounded by bulk thermal insulation. Select appropriate equipment to suitably protect the circuits. Write the current rating as appropriate for each protection device.

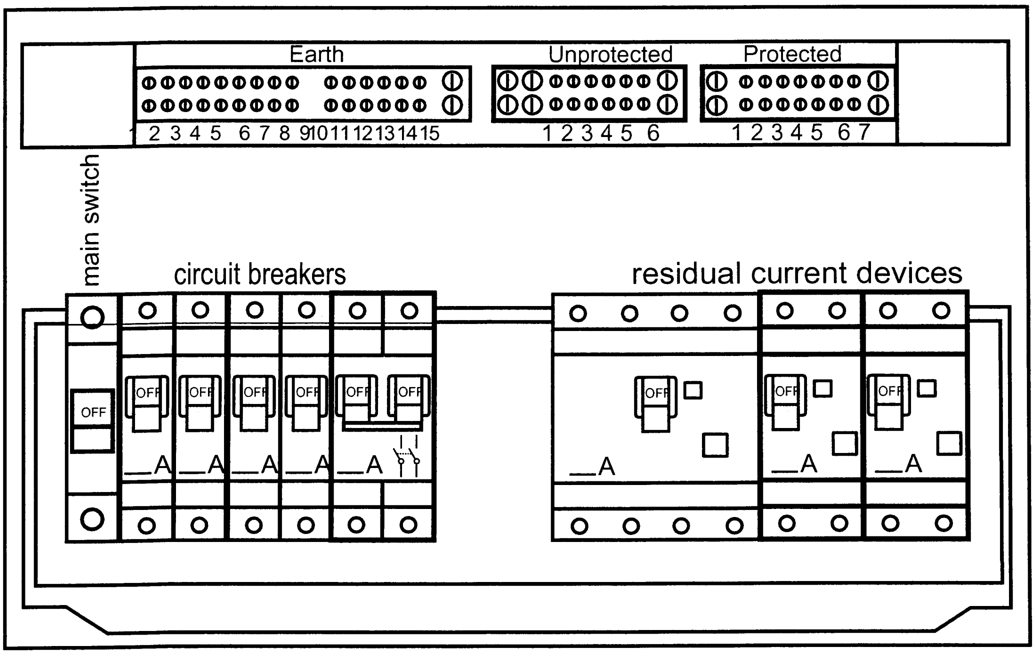

Figure 4.5 One 2-pole RCD for light circuit and one 4-pole RCD for power circuits

2. The equipment shown in Figure 4.6 is for a switchboard in a domestic installation. Show on the diagram the necessary Active, Neutral and Earth connections for the following:

- Circuit 1 22 lighting points
- Circuit 2 12 double socket outlets
- Circuit 3 11 double socket outlets

Three separate two-pole RCD's protect the light and power circuits.

Arrangement of the circuits places them partially surrounded by bulk thermal insulation. Select appropriate equipment to suitably protect the circuits. Write the current rating as appropriate for each protection device.

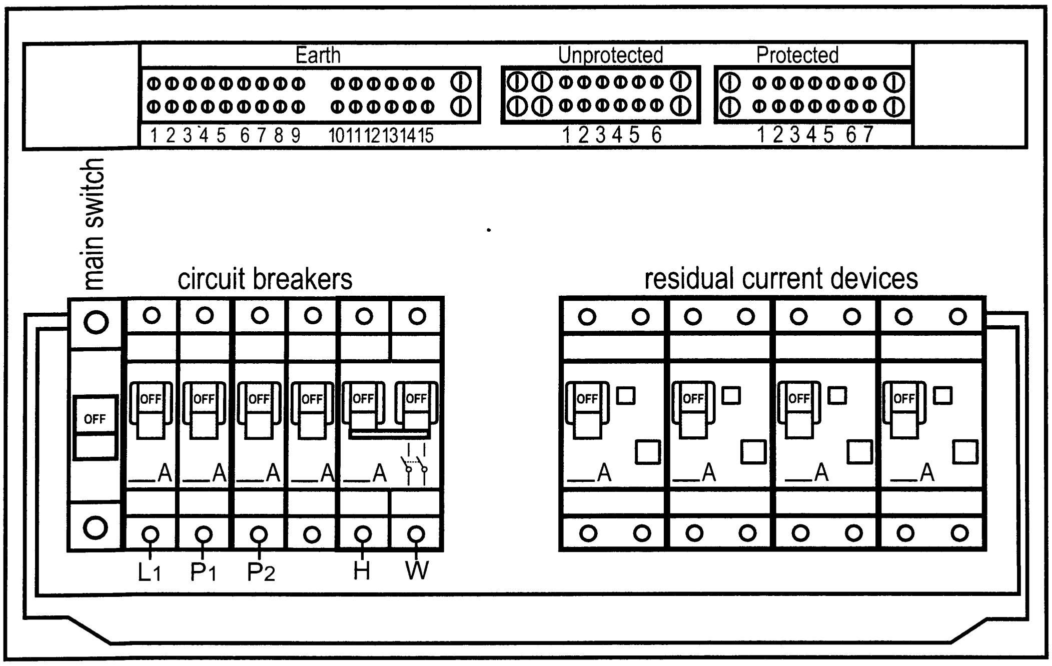

Figure 4.6 Two-pole RCDs protecting light and power circuits

3. The equipment shown in Figure 4.7 is for a switchboard in a domestic installation. Show on the diagram the necessary Active, Neutral and Earth connections for the following:

- Circuit 1 22 lighting points
- Circuit 2 12 double socket outlets
- Circuit 3 11 double socket outlets

Three separate two-pole combination RCD/MCB's protect light and power circuits.

Arrangement of the circuits places them partially surrounded by bulk thermal insulation. Select appropriate equipment to suitably protect the circuits. Write the current rating as appropriate for each protection device.

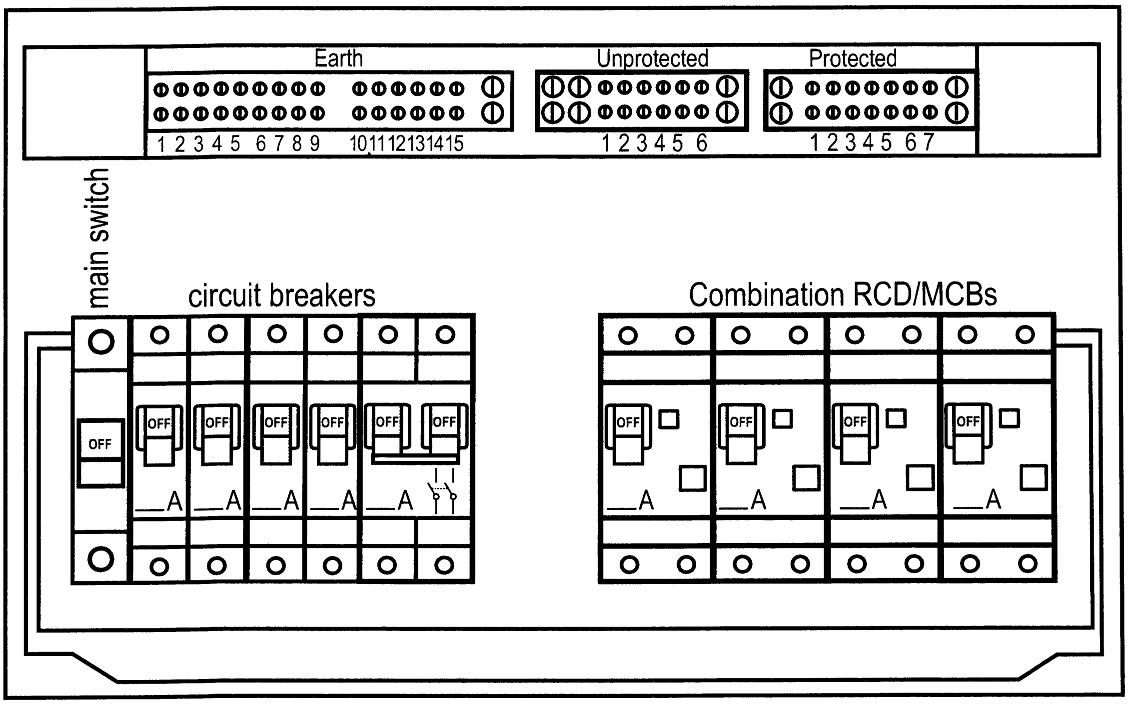

Figure 4.7 Two-pole combination RCD/MCB

Review questions

These questions will help you revise what you have learnt in this topic.

1. Fuses and circuit breakers are installed to protect:
   (A) electrical appliances
   (B) electrical cables
   (C) electrical loads
   (D) persons and livestock.

2. If a cable supplying a load that is operating at 50% overload, the power dissipated by the cable will be:
   (A) 25% of its original value
   (B) 50% of its original value
   (C) 150% of its original value
   (D) 225% of its original value.

3. When installing fuses in a final subcircuit, the current carrying capacity of the cables are re-rated by a factor of:
   (A) 0.7
   (B) 0.8
   (C) 0.9
   (D) 1.25.

4. A current that results from a fault of negligible resistance occurring between live conductors having a difference in potential under normal operating conditions is:
   (A) an earth loop current
   (B) a fault current
   (C) an overload
   (D) a short circuit.

5. When comparing the HRC fuse with a rewireable fuse, the greatest advantage one has over the other is:
   (A) the rewireable fuse gives better protection against fault currents
   (B) the HRC fuse extinguishes the arcing at the eutectic point
   (C) the HRC fuse is inexpensive
   (D) the rewireable fuse allows an overload to exist for a longer period.

6. The term d*iscrimination* as applied to circuit protection means:
   (A) the circuit protective device closest to the fault or over-current should operate before any upstream devices
   (B) the fuse or circuit breaker with the highest fault current rating should operate first
   (C) circuit protection on the main switchboard should be the first to operate
   (D) the circuit protection should be able to distinguish between a short circuit to earth and a short circuit between live conductors.

7. The *trip-free* characteristic of a circuit breaker means it:
   (A) cannot be held on while a fault exists
   (B) will not trip on overloads under 150% of rated current
   (C) is rated at more than 6 kA
   (D) will not be subjected to nuisance tripping.

8. The conventional tripping current of a miniature circuit breaker is:
   (A) equal to the nominal breaker rating
   (B) 0.9 times the nominal breaker rating
   (C) 1.45 times the nominal breaker rating
   (D) 1.6 times the nominal breaker rating.

9. The circuit protection device best suited for quick isolation of a fault current would be a:
   (A) thermal circuit breaker
   (B) rewireable fuse
   (C) magnetic circuit breaker
   (D) RCD.

10. The circuit protection device that can operate quickly; interrupt higher values of current, and completely contains the energy dissipated by the fusing element is a:
   (A) rewireable fuse
   (B) HRC fuse
   (C) RCD
   (D) thermal circuit breaker.

11. Circuits in a domestic installation are protected by an RCD which has a maximum leakage current of:
   (A) 20 mA
   (B) 30 mA
   (C) 80 mA
   (D) 100 mA.

12. Where a single RCD is fitted to protect all circuits in a domestic installation, it should have:
   (A) a trip current of 30 mA and a rated switching current of 63 A
   (B) a trip current of 30 mA and a rated switching current of not less than the installation maximum demand
   (C) a trip current of 100 mA and a rated switching current of 63 A
   (D) a trip current of 100 mA and a rated switching current of 100 A.

13. In a domestic installation, the circuits requiring RCD protection are:
   (A) all circuits
   (B) light and power circuits
   (C) power circuits with the exception of outlets for refrigerators and freezers
   (D) all circuits supplying socket outlets.

14. A device intended to isolate the supply to protected circuits in the event of a current flow to earth that exceeds a predetermined value is a:
   (A) rewireable fuse
   (B) HRC fuse
   (C) miniature circuit breaker
   (D) residual current device.

15. Where socket outlets and lighting circuits in a domestic installation are protected by RCDs, the maximum rated residual current of the device must no exceed:
   (A) 10 mA
   (B) 30 mA
   (C) 100 mA
   (D) 20 A.

16. What is a short-circuit current?

AS/NZS 3000 Reference: ____________________

17. What is an overload current?

AS/NZS 3000 Reference: ____________________

18. What is a fault current?

AS/NZS 3000 Reference: ____________________

19. What is a fuse?

AS/NZS 3000 Reference: ____________________

20. What is a circuit breaker?

AS/NZS 3000 Reference: ____________________

21. What is a prospective fault current?

AS/NZS 3000 Reference: ____________________

Review questions

22. What is meant by inverse current-time characteristic?

23. What can cause excess current in a circuit?

24. What effects can excess current have on an electrical circuit?

25. Briefly describe the construction of a HRC fuse.

26. Briefly describe how the de-ion grid aids in arc extinction.

27. An energy distributor states that a prospective short-circuit current of 45 kA is to be assumed at a point of supply at a main switchboard, which feeds a main distribution board (DB1) through 35 m of 95 mm^2 cable. This distribution board supplies another distribution board (DB2) through 30 m of 35 mm^2 cable. Calculate the fault level at the second distribution board. (Hint use Table 4.1 and Figure 4.8).

Table 4.1 Cable impedance (Ohm) for copper

Nominal conductor csa (mm^2)	Nominal conductor resistance at 20°C (Ohm per metre)	Length of cable (m)							
		5	10	15	20	25	30	40	50
1	0.0177	0.0885	0.1770						
1.5	0.0119	0.0595	0.1190	0.1785	values above this line reduce fault currents to less than 2kA				
2.5	0.0072	0.0360	0.0720	0.1080	0.1440	0.1800			
4	4.52×10^{-3}	0.0226	0.0452	0.0678	0.0904	0.1130	0.1356	0.1808	
6	3.02×10^{-3}	0.0151	0.0302	0.0453	0.0604	0.0755	0.0906	0.1208	0.1510
10	1.79×10^{-3}	0.0090	0.0179	0.0269	0.0358	0.0448	0.0537	0.0716	0.0895
16	1.13×10^{-3}	0.0057	0.0113	0.0170	0.0226	0.0283	0.0339	0.0452	0.0565
25	6.60×10^{-4}	0.0033	0.0066	0.0099	0.0132	0.0165	0.0198	0.0264	0.0330
35	5.14×10^{-4}	0.0026	0.0051	0.0077	0.0103	0.0129	0.0154	0.0206	0.0257
50	3.79×10^{-4}	0.0019	0.0038	0.0057	0.0076	0.0095	0.0114	0.0152	0.0190
70	2.62×10^{-4}	0.0013	0.0026	0.0039	0.0052	0.0066	0.0079	0.0105	0.0131
95	1.95×10^{-4}	0.0010	0.0020	0.0029	0.0039	0.0049	0.0059	0.0078	0.0098
120	1.50×10^{-4}	0.0008	0.0015	0.0023	0.0030	0.0038	0.0045	0.0060	0.0075
150	1.22×10^{-4}	0.0006	0.0012	0.0018	0.0024	0.0031	0.0037	0.0049	0.0061
185	9.72×10^{-5}	0.0005	0.0010	0.0015	0.0019	0.0024	0.0029	0.0039	0.0049
240	7.40×10^{-5}	0.0004	0.0007	0.0011	0.0015	0.0019	0.0022	0.0030	0.0037
300	5.90×10^{-5}	0.0003	0.0006	0.0009	0.0012	0.0015	0.0018	0.0024	0.0030
400	4.61×10^{-5}	0.0002	0.0005	0.0007	0.0009	0.0012	0.0014	0.0018	0.0023

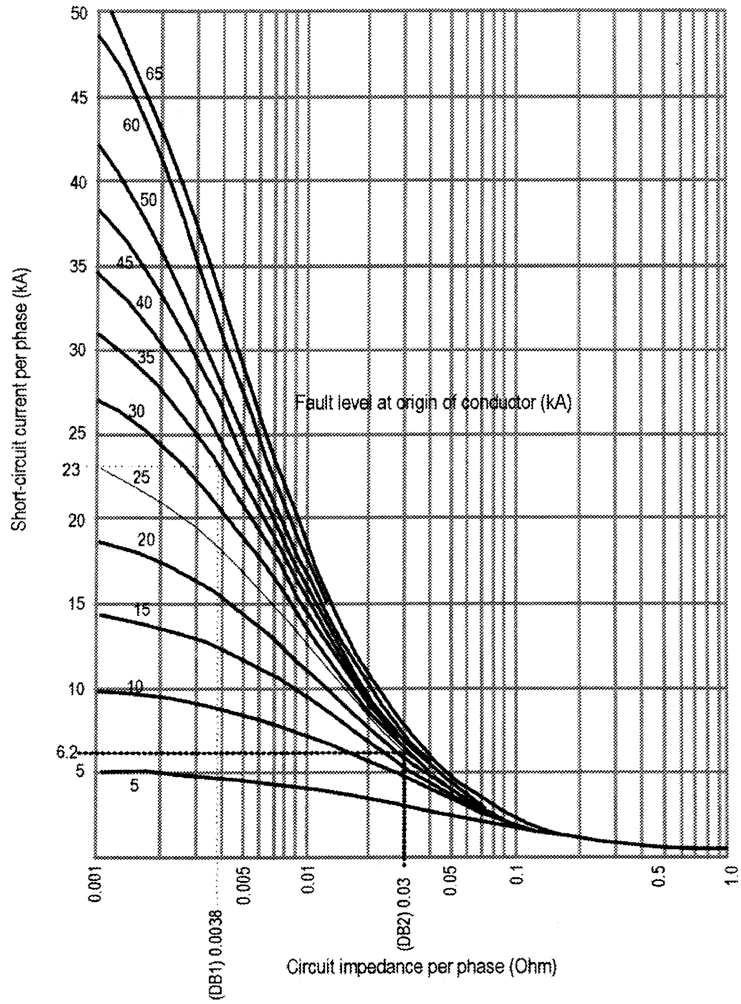

Figure 4.8 Prospective short-circuit currents

28. The equipment shown in Figure 4.9 is for a switchboard in a domestic installation. Show on the diagram the necessary Active, Neutral and Earth connection for the following:

- Circuit 1 17 lighting points
- Circuit 2 10 double socket outlets
- Circuit 3 9 double socket outlets
- Circuit 4 15 lighting points

Arrangement of the circuits places them partially surrounded by bulk thermal insulation. Select appropriate equipment to suitably protect the circuits.

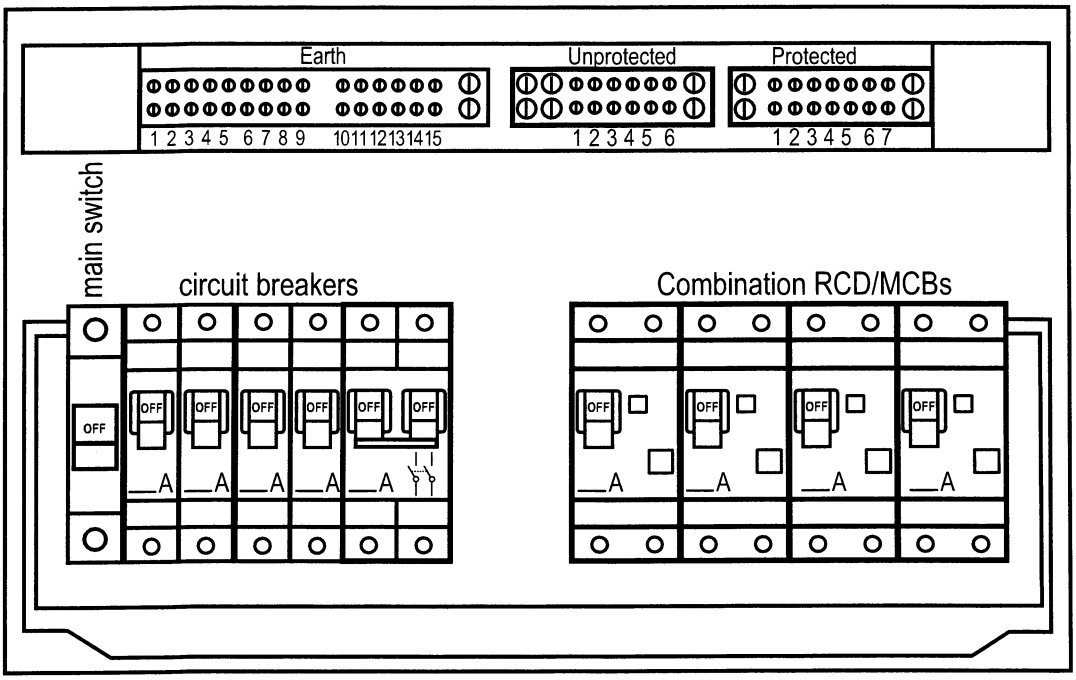

Figure 4.9

5. Switchgear and Control Gear

What this topic covers

This topic will provide exercises in the AS/NZS 3000: 2000 requirements for the safe selection of electrical equipment in electrical installations as a revision and preparation for the Electrical Systems Safety assessment. It covers part of the critical knowledge and skills for the selection of motor starters to meet local supply authority service rules.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- reasons for limiting motor starting currents
- regulatory requirements that apply to starting, control and protection of induction motors
- common motor starters
- operating principle of common motor starters
- main advantages and disadvantages of common motor starters
- the effects on line current, motor current and motor torque when using reduced-voltage motor starters
- common applications for various motor starters.

Where you will find information

- Jenneson J., *Electrical Principles for the Electrical Trades*, 5th Edition, McGraw-Hill Book Company, Roseville, NSW, 2003.
- Local supply authorities services rules
- *AS/NZS 3000:2000 Wiring rules,* Section 2, Standards Australia.

Student exercise 5.1 Limitation of starting current

Familiarise yourself with *Clause 4.3.4* before attempting the following questions.

1. When must a motor have control equipment incorporating means of protection against overload of the motor?

2. Generally a motor must incorporate over-temperature protection. What exemptions are permissible?

Familiarise yourself with *Clause 4.2.1* before attempting the following questions.

3. What are the requirements for devices used for isolation and switching of an electric motor?

4. What are the requirements for protecting electric motors against restarting or reversing?

Familiarise yourself with *Clause 2.8.4* before attempting the following questions.

5. What are the requirements for devices used for switching off for mechanical maintenance?

6. What features should devices used for switching off for mechanical maintenance have?

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7. How should devices used for switching off for mechanical maintenance be identified?

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Student exercise 5.2 Direct-on-line motor starter

1. Draw the control and power circuits, in schematic form, of a direct-on-line motor starter in the space provided.

2. Expand your diagram to show additional stop buttons in series and additional start buttons in parallel.

3. Using your schematic as a guide, explain the sequence of operation.

4. Detail a procedure for determining faults in the control circuit of a DOL motor starter.

Student exercise 5.3 Star - Delta motor starter

1. Draw the control and power circuits, in schematic form, of a Star - Delta motor starter in the space provided using the following description as a guide.
   Circuit operation:

   - when the start button is processed - K_1 closes and the hold in contact keeps the contactor energised
   - time delay relay energises and begins to countdown
   - K_2 energises making the star point
   - after the time delay K_2 de-energises
   - with K_2 de-energised, K_3 energises making the delta connection
   - at any time, operation of overload or stop button stops the motor.

2. A 400 V, 3-phase induction motor is to be started by a star-delta starter. When started DOL the motor has a starting current of 48 A and the starting torque is 35 Nm. Calculate starting current and starting torque when started using a star-delta starter.

3. Sketch a typical torque - speed curve for the above motor when started using a star-delta starter.

Student exercise 5.4 Primary resistance motor starter

1. Draw the control and power circuits, in schematic form, of a primary resistance motor starter in the space provided using the following description as a guide.

   Circuit operation:

   - when the start button is processed - K_1 closes and the hold in contact keeps the contactor energised
   - time delay relay energises and begins countdown
   - after the time delay K_2 energises and short-circuits the resistors
   - at any time, operation of overload or stop button stops the motor

2. Sketch a typical torque - speed curve for the above motor when started using a primary resistance starter.

3. Detail a procedure for determining faults in the control circuit of a primary resistance motor starter.

Student exercise 5.5 Auto transformer motor starter

1. Draw the control and power circuits, in schematic form, of a auto transformer motor starter in the space provided using the following description as a guide.

   Circuit operation:

   - when the start button is processed - K_1 closes - connecting the transformer in star
   - contactor K_3 also energises hold in contacts (K_{1-4} and K_{3-4}) to keep contactors K_1 and K_3 energised
   - time delay on K_3 begins the countdown
   - K_3 power contacts connect the transformer to line, so reducing the voltage applied to the motor
   - after time delay, K_1 de-energises
   - contactor K_2 then energises applying full-voltage to the motor
   - at any time, operation of overload or stop button stops the motor

2. Sketch a typical torque - speed curve for the above motor when started using an auto-transformer starter.

3. A 400V, 3-phase induction motor is started by an auto transformer starter using a 75% tapping. When started DOL the starting current is 65 A and starting torque is 45 Nm. Calculate motor current, starting current and starting torque when started using the auto transformer.

Student exercise 5.6 Secondary resistance motor starter

1. Draw the control and power circuits, in schematic form, of a secondary resistance motor starter in the space provided using the following description as a guide.

   Circuit operation:

   - when the start button is processed – K_1 closes and the hold in contact keeps the contactor energised
   - time delay contact on K_1 begins to countdown
   - after the time delay contactor K_2 energises and short-circuits the resistors
   - at any time, operation of overload or stop button stops the motor.

2. Sketch a typical torque - speed curve for the above motor when started using a secondary resistance starter.

3. Detail a procedure for determining faults in the control circuit of a secondary resistance motor starter.

Review questions

These questions will help you revise what you have learnt in this topic.

1. What is the effect of changing the phase sequence of the 3-phase supply to an induction motor?
   (A) the motor will overheat
   (B) the motor will operate with reduced torque
   (C) there is no effect on the motor
   (D) motor will reverse direction of rotation.

2. What is the effect on line power factor of increasing the load on an induction motor toward full-load?
   (A) Power factor increases
   (B) Power factor decreases
   (C) Power factor remains constant
   (D) Power factor is unity.

3. What is a disadvantage of reducing the voltage when starting a 3-phase induction motor?
   (A) less mechanical force is exerted on the rotor windings
   (B) there is a greater disturbance of line currents
   (C) the starting torque is reduced
   (D) the motor accelerates more rapidly.

4. What is the number of active conductors between the starter and motor stator for a star-delta motor starter?
   (A) 2
   (B) 3
   (C) 4
   (D) 6.

5. The resistor banks of a secondary resistance motor starter are connected in:
   (A) series with the stator windings
   (B) parallel with the stator windings
   (C) star configuration across the rotor slip rings
   (D) star configuration for starting and then delta for running.

6. What are the AS/NZS 3000 requirements for the limitation of overload currents for motors greater than 370 watts?

   AS/NZS 3000 Reference: ____________________

7. What are the AS/NZS 3000 requirements for the automatic restarting of motors?

   AS/NZS 3000 Reference: ____________________

Review questions

8. What are the AS/NZS 3000 requirements for control switches for motors?

AS/NZS 3000 Reference: ____________________

9. What are the AS/NZS 3000 requirements for isolating motors during mechanical maintenance?

AS/NZS 3000 Reference: ____________________

10. A 400 volt, 3-phase induction motor draws 80 A and produces 60 Nm of starting torque when started direct on line. Calculate the starting current and starting torque if the motor is started through a star-delta starter.

11. A 400 volt, 3-phase induction motor draws 140 A and produces 300 Nm of starting torque when started direct on line. Calculate the line starting current and motor starting torque if the motor is started through an auto-transformer starter having a 70% tap.

12. A local electrical supply authority requires the starting current drawn by a 3-phase, 400 volt induction motor in a non-domestic application to be limited to 3.3 k + 53 amperes where k is the continuous output rating in kW of the largest motor in the installation. Determine a suitable motor starter for a 45 kW motor having a full-load current of 79 A and DOL starting current of 410 A. (Show all calculations to prove your answer, the largest motor in the installation is 45 kW).

Notes

6. Electrical Installation Design - Maximum Demand

What this topic covers

This topic will provide exercises in the AS/NZS 3000: 2000 requirements for the design of safe electrical installations as a revision and preparation for the Electrical Systems Safety assessment. In particular you will consider the design of an installation on the basis of maximum demand.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- designing a safe single domestic electrical installation based on maximum demand
- designing a safe multiple domestic electrical installation based on maximum demand
- designing a safe non-domestic electrical installation based on maximum demand
- justifying your designs.

Where you will find information

The following references will help you in completing the exercises and review questions in the topic.

- *AS/NZS 3000:2000 Wiring rules*, Section 1 and Apprendix C, Standards Australia.
- *HB300 - 2001, Electrical Installations*, Part 1, Standards Australia.
- Pethbridge K. and Neeson I., *Electrical Wiring Practice K.*, 6th Edition, Vol.2, McGraw-Hill, Sydney, Chapter 15.

Student exercise 6.1 Maximum demand for domestic installation

Calculate the maximum demand for a single domestic installation using the electrical schedule detailed in Appendix A of this resource manual.

Table 6.1

Load group	*Load group*	*Qty*	*Calculation*	*Demand (A)*
			Maximum demand	

Student exercise 6.2 Maximum demand for multiple installation

1. Calculate the maximum demand for a multiple domestic installation using the electrical schedule detailed in Appendix B of this resource manual.
2. Calculate the maximum demand for a single living unit (single domestic installation) using the electrical schedule detailed in Appendix B of this resource manual.

Table 6.2 - Multiple living unit

Load group	*Load group*	*Qty*	*Calculation*	*Demand (A)*
			Maximum demand	

Table 6.3 - Communal load

Load group	*Load group*	*Qty*	*Calculation*	*Demand (A)*
			Maximum demand	

Table 6.4 - Single living units

Load group	*Load group*	*Qty*	*Calculation*	*Demand (A)*
			Maximum demand	

Total maximum demand	

Student exercise 6.3 Maximum demand for commercial installation

Calculate the maximum demand for a commercial installation using the electrical schedule detailed in Appendix C of this resource manual.

Table 6.5

Load group	*Load description*	*Qty*	*Calculation*	*Demand (Red)*	*Demand (White)*	*Demand (Blue)*
			Maximum demand			

Review questions

These questions will help you revise what you have learnt in this topic.

For each of the following, calculate the maximum demand of the individual load groups using Appendix C of AS/NZS 3000:2000 giving reference to load group and Table.

1. This portion of a 230-volt single-phase domestic installation has 32 lighting points.

   Table No: ______________________________

   Load group and column reference: ______________________________

   Demand: ______________________________

2. This portion of a 230 volt single-phase domestic installation has 1.725 kW of tennis court lighting.

   Table No: ______________________________

   Load group and column reference: ______________________________

   Demand: ______________________________

3. This portion of a 230 volt single-phase domestic installation has a 4.6 kW wall oven and 6.4 kW hot plate.

   Table No: ______________________________

   Load group and column reference: ______________________________

   Demand: ______________________________

4. This portion of a 230 volt single-phase domestic installation has a 4.6 kW spa heater.

   Table No: ______________________________

   Load group and column reference: ______________________________

   Demand: ______________________________

Review questions

5. This portion of a 230 volt single-phase non-domestic installation has sixty 38 watt fluorescent lights each having a ballast consuming 7 watts and operating at a power factor of 0.45 lagging.

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Table No: ____________________

Load group and column reference: ____________________

Demand: ____________________

6. This portion of a 230 volt single-phase non-domestic installation has 20 metres of track lighting.

Table No: ____________________

Load group and column reference: ____________________

Demand: ____________________

7. This portion of a 230 volt single-phase non-domestic installation has 9.2 kW hotplates.

Table No: ____________________

Load group and column reference: ____________________

Demand: ____________________

8. This portion of a 400 volt three-phase non-domestic installation has two lift motors rated at 9.4 A each.

Table No: ____________________

Load group and column reference: ____________________

Demand: ____________________

9. This portion of a 230 volt single-phase non-domestic installation has two 4 kW X-ray units, each having a full-load current of 20 A.

Table No: ____________________

Load group and column reference: ____________________

Demand: ____________________

10. Calculate the maximum demand of a three-phase sub-main to a non-air-conditioned portion of a factory having the following load:
    - 1 only 3-phase 400 V motor having full load current of 18 A
    - 2 only 3-phase 400 V motors a having a full load current of 8 A each
    - 36 only 10 A single socket outlets (3 circuits)
    - 33 only triple 36 W fluorescent luminaires having a rating of 0.35 A each (3 circuits)

Load group	*Load description*	*Qty*	*Calculation*	*Demand (Red)*	*Demand (White)*	*Demand (Blue)*
			Maximum demand			

11. Calculate the maximum demand of a three-phase consumer main to a block of 21 town houses units each having following load:
    - 18 only lighting points
    - 6 only single socket outlets
    - 12 only double socket outlets
    - 3.6 kW permanently connected air conditioner having full-load current of 18 A
    - 9.6 kW upright range
    - 4.6 kW off peak hot water service

Load group	*Load group*	*Qty*	*Calculation*	*Demand (A)*
			Maximum demand	

Notes

7. Electrical Installation Design - Circuit Arrangements

What this topic covers

This topic will provide exercises in the AS/NZS 3000: 2000 requirements for the design of safe electrical installations as a revision and preparation for the Electrical Systems Safety assessment. In particular you will consider the design of an installation on the basis of circuit arrangement and installation methods.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- designing a safe single domestic electrical installation based on circuit arrangement
- designing a safe multiple domestic electrical installation based on circuit arrangement
- designing a safe non-domestic electrical installation based on circuit arrangement
- designing a safe single domestic electrical installation based on choosing a suitable wiring system
- designing a safe multiple domestic electrical installation based on choosing a suitable wiring system
- designing a safe non-domestic electrical installation based on choosing a suitable wiring system.

Where you will find information

The following references will help you in completing the exercises and review questions in the topic.

- *AS/NZS 3000:2000 Wiring rules*, Sections 1 & 3, Standards Australia.
- *HB300 - 2001, Electrical Installations*, Part 1, Standards Australia.
- Pethbridge K. and Neeson I., *Electrical Wiring Practice K.*, 6th Edition, Vol.2, McGraw-Hill, Sydney, Chapter 15.

Student exercise 7.1 Circuit arrangement

1. Complete Table 7.1 to show the circuit arrangements for the single domestic installation using the electrical schedule detailed in Appendix A of this resource manual.

Table 7.1 Domestic installation

Circuit	*Description*	*Points*	*Demand*

Why did you divide the installation into these circuits?

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2. Complete Table 7.2 to show the circuit arrangements for a single living unit using the electrical schedule detailed in Appendix B of this resource manual.

Table 7.2 Single living unit installation

Circuit	*Description*	*Points*	*Demand*

Why did you divide the installation into these circuits?

____

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____

Student exercise 7.2 Choosing wiring systems for installation

1. Complete Table 7.3 by selecting suitable wiring systems for the single domestic installation detailed in the electrical schedule of Appendix A.

Table 7.3 Wiring systems for domestic installation

Circuit	*Wiring system*	*Reason*
Service mains		
Lighting		
Socket outlets		
Cook-top		
Oven		
Water heater		
Air conditioner		

2. Complete Table 7.4 and Table 7.5 by selecting suitable wiring systems for the multiple domestic installation detailed in the electrical schedule of Appendix B.

Table 7.4 Wiring systems for multiple domestic installation

Individual unit		
Circuit	*Wiring systems*	*Reason*
Sub-mains (Unit)		
Lighting (Unit)		
Socket outlets (Unit)		
Cook-top (Unit)		
Oven (Unit)	.	
Water heater (Unit)		
Air conditioner (Unit)		

Table 7.5 Wiring systems for multiple domestic installation

Individual unit		
Circuit	*Wiring systems*	*Reason*
Service mains		
Lighting (Bollards)		
Lighting (Barbecue)		
Lighting (Swimming)		

3. Complete Table 7.6 by selecting suitable wiring systems for the non-domestic installation detailed in the electrical schedule of Appendix C.

Table 7.6 Wiring systems for non-domestic installation

Circuit	*Wiring system*	*Reason*
Sub-mains		
Lighting (office)		
Socket outlets (office)		
Lighting (factory)		
Socket outlets (factory)		
3-phase outlets		
Water heater		

Review questions

These questions will help you revise what you have learnt in this topic.

1. Complete the following table by entering details of an appropriate wiring system for each given application in a domestic installation. The dwelling is of brick-veneer construction on a concrete slab and has a trussed roof covered with masonry tiles. The supply authority provides 3-phase electrical power via underground street mains.

Circuit	*Installation notes*	*Wiring system*
Service mains	3- phase supply required. Connects to supply authority's underground mains	
Lighting	Ceiling contains thermal insulation by way of batts.	
Socket Outlets	Exterior walls contain thermal insulation by way of batts.	
Hot water service	Freestanding mains pressure located externally.	
Range	Single-phase supply required. Ceiling and exterior walls contain thermal insulation by way of batts	
Air conditioner	3-phase supply required. Located externally. Ceiling and exterior walls contain thermal insulation by way of batts.	

2. Complete the following table by entering details of an appropriate wiring system for each given application in a non-domestic installation. The factory unit has pre-cast concrete walls attached to a steel frame support on a concrete slab. The metal roof sheeting attaches directly to the roof support members and has thermal insulation on the underside. The supply authority provides 3-phase electrical power via on-site substation.

Circuit	*Installation notes*	*Wiring system*
Service mains	3- phase supply required. Connects to main switchboard	
Lighting	Suspended fluorescent luminaire	
Socket Outlets	Mounted at 1200 high in factory Office constructed of plasterboard lined timber frame	
Hot water service	Freestanding mains pressure located in washroom	
Air conditioner	Single-phase supply required. Located in lieu of window in office	

8. Electrical Installation Design - Voltage Drop

What this topic covers

This topic will provide exercises in the AS/NZS 3000: 2000 and AS/NZS 3008.1.1 requirements for the design of safe electrical installations as a revision and preparation for the Electrical Systems Safety assessment. In particular you will consider the design of an installation on the basis of voltage drop.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- designing a safe single domestic electrical installation based on voltage drop
- designing a safe multiple domestic electrical installation based on voltage drop
- designing a safe non-domestic electrical installation based on voltage drop
- justifying your design.

Where you will find information

The following references will help you in completing the exercises and review questions in the topic.

- *AS/NZS 3000:2000 Sections 1 and 3*, Standards Australia
- *AS/NZS 3008.1.1 Electrical Installations - Selection of cables,* Standards Australia
- *HB300 - 2001, Electrical Installations*, Part 1, Standards Australia.
- Pethbridge K. and Neeson I., *Electrical Wiring Practice K.*, 6th Edition, Vol.2, McGraw-Hill, Sydney, Chapter 15.

Student exercise 8.1 Voltage drop based on mV/A.m

A 400-volt, three-phase final sub-circuit in a non-domestic installation consists of three V90 single core thermoplastic and sheathed with copper conductors supplying a 45-ampere resistive load. The circuit is enclosed in heavy-duty rigid thermoplastic conduit with no other circuits and saddled to a building structure that places it open to the air. Circuit protection is by way of circuit breaker and the distance from the switchboard to the load terminals of the equipment is 90 metre.

Calculate the minimum permissible cable size based on voltage drop.

Student exercise 8.2 Voltage drop based on mV/A.m

A 400-volt, three-phase final sub-circuit in a non-domestic installation consists of three V90 single core thermoplastic and sheathed copper conductors supplying a 30-ampere resistive load. The circuit is enclosed in heavy-duty rigid thermoplastic conduit with no other circuits. The conduit is buried in the ground having an ambient soil temperature of 25°C and has a top cover of 0.55 metre. Circuit protection is by way of HRC fuses and the distance from the switchboard to the load terminals of the equipment is 65 metre.

Calculate the minimum permissible cable size based on voltage drop.

Student exercise 8.3 Voltage drop based on mV/A.m

A 400-volt, three-phase final sub-circuit in a non-domestic installation consists of three, 4 mm^2 V90 single core thermoplastic and sheathed copper conductors supplying a 28-ampere resistive load. The cables are clipped to the building structure in trefoil formation and installed in single circuit configuration, unenclosed in air. Circuit protection is by way of HRC fuses. The length of circuit conductors is 42 metre.

It is necessary to relocate the equipment within the same building. It is proposed to extend the existing 4 mm^2 circuit. How much farther is it possible to extend this circuit so as not to exceed the permissible voltage drop, given the per cent voltage drop to the distribution board is 1.8%.

Student exercise 8.4 Voltage drop based on mV/A.m

A 230-volt, single-phase final sub-circuit in a non-domestic installation consists of a two-core and earth, flat V90 thermoplastic and sheathed copper conductors supplying a 36-ampere pottery kiln (resistive load). The cable is clipped to the building structure and installed in single circuit configuration, unenclosed in air. Circuit protection is by way of circuit breaker and the distance from the switchboard to the load terminals of the equipment is 50 metres.

Calculate the minimum permissible cable size based on voltage drop.

Student exercise 8.5 Voltage drop based on mV/A.m

Calculate the voltage drop in each segment of a three-phase, 400-volt non-domestic installation consisting of the following:

Consumer main:

Phases:	3
Maximum demand:	55 A
Route length:	15 m
Cable size:	16 mm^2
Cable configuration:	V90 single core thermoplastic and sheathed copper conductors
Cable installation:	The circuit is enclosed in heavy-duty rigid thermoplastic conduit with no other circuits. Conduit is buried in the ground having an ambient soil temperature of 25°C and has a top cover of 0.65 m

Sub-main:

Phases:	3
Maximum demand:	40 A
Route length:	45 m
Cable size:	10 mm^2
Cable configuration:	V90 single core thermoplastic and sheathed copper conductors
Cable installation:	The cables are clipped to the building structure in trefoil formation and installed in single circuit configuration, unenclosed in air

Final sub-circuit:

Phases:	1
Maximum demand:	18 A
Route length:	30 m
Cable size:	4 mm^2
Cable configuration:	V90 two-core and earth thermoplastic and sheathed copper conductors
Cable installation:	The cables are clipped to the building structure and installed in single circuit configuration, unenclosed in air

Consumer main:

Table No: ______________________________

mV/A.m rating: ______________________________

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Sub-main:

Table No: ______________________________

mV/A.m rating: ______________________________

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Final sub-circuit:

Table No: ______________________________

mV/A.m rating: ______________________________

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Review questions

These questions will help you revise what you have learnt in this topic.

1. A 400 volt, three-phase final sub-circuit in a non-domestic installation consists of three V90 single core thermoplastic and sheathed with copper conductors supplying a 55-ampere resistive load. The circuit is enclosed in heavy-duty rigid thermoplastic conduit with no other circuits and saddled to a building structure that places it open to the air. Circuit protection is by way of circuit breaker and the distance from the switchboard to the load terminals of the equipment is 75 metre.

   Calculate the minimum permissible cable size based on voltage drop.

   Table No: ______________________________

   mV/A.m rating: ______________________________

2. A 400 volt, three-phase final sub-circuit in a non-domestic installation consists of three V90 single core thermoplastic and sheathed copper conductors supplying a 35-ampere resistive load. The circuit is enclosed in heavy-duty rigid thermoplastic conduit with no other circuits. The conduit is buried in the ground having an ambient soil temperature of 25°C and has a top cover of 0.55 metre. Circuit protection is by way of HRC fuses and the distance from the switchboard to the load terminals of the equipment is 54 metre.

   Calculate the minimum permissible cable size based on voltage drop.

   Table No: ______________________________

   mV/A.m rating: ______________________________

Review questions

3. A 400 volt, three-phase final sub-circuit in a non-domestic installation consists of three, 6 mm^2 V90 single core thermoplastic and sheathed copper conductors supplying a 34-ampere resistive load. The cables are clipped to the building structure in trefoil formation and installed in single circuit configuration, unenclosed in air. Circuit protection is by way of HRC fuses. The length of circuit conductors is 45 metre.

   It is necessary to relocate the equipment within the same building. It is proposed to extend the existing 6 mm^2 circuit. How much farther is it possible to extend this circuit so as not to exceed the permissible voltage drop, given the per cent voltage drop to the distribution board is 2.2%.

   Table No: ______________________________

   mV/A.m rating: ______________________________

   ____

   ____

   ____

   ____

   ____

4. A 230 volt, single-phase final sub-circuit in a non-domestic installation consists of a two-core and earth, flat V90 thermoplastic and sheathed copper conductors supplying a 32-ampere pottery kiln (resistive load). The cable is clipped to the building structure and installed in single circuit configuration, unenclosed in air. Circuit protection is by way of circuit breaker and the distance from the switchboard to the load terminals of the equipment is 65 metre.

   Calculate the minimum permissible cable size based on voltage drop.

   Table No: ______________________________

   mV/A.m rating: ______________________________

   ____

   ____

   ____

   ____

   ____

5. Calculate the voltage drop in each segment of a three-phase, 400-volt non-domestic installation consisting of the following:

Consumer main:

Phases:	3
Maximum demand:	45 A
Route length:	25 m
Cable size:	16 mm^2
Cable configuration:	V90 single core thermoplastic and sheathed copper conductors
Cable installation:	The circuit is enclosed in heavy-duty rigid thermoplastic conduit with no other circuits. Conduit is buried in the ground having an ambient soil temperature of 25°C and has a top cover of 0.65 m

Sub-main:

Phases:	3
Maximum demand:	35 A
Route length:	35 m
Cable size:	10 mm^2
Cable configuration:	V90 single core thermoplastic and sheathed copper conductors
Cable installation:	The cables are clipped to the building structure in trefoil formation and installed in single circuit configuration, unenclosed in air

Final sub-circuit:

Phases:	1
Maximum demand:	20 A
Route length:	35 m
Cable size:	4 mm^2
Cable configuration:	V90 two-core and earth thermoplastic and sheathed copper conductors
Cable installation:	The cables are clipped to the building structure and installed in single circuit configuration, unenclosed in air

Does this portion of the installation comply with the voltage drop requirements of AS/NZS 3000?

Review questions

Consumer main:

Table No: ______________________

mV/A.m rating: ______________________

____

____

____

____

Sub-main:

Table No: ______________________

mV/A.m rating: ______________________

____

____

____

____

Final sub-circuit:

Table No: ______________________

mV/A.m rating: ______________________

____

____

____

____

Notes

9. Selection of Cables and Protective Devices

What this topic covers

This topic will provide exercises in the AS/NZS 3008.1.1 and AS/NZS 3000:2000 requirements for the design of safe electrical installations as a revision and preparation for the Electrical Systems Safety assessment. In particular you will consider the design of an installation on the basis of cable selection.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- cable selection based on current-carrying capacity
- producing evidence that cable size complies with safety requirements
- selection of fault protection devices.

Where you will find information

The following references will help you in completing the exercises and review questions in the topic.

- *AS/NZS 3000:2000 Wiring rules,* Standards Australia.
- *AS/NZS 3008.1.1 Electrical Installations - Selection of Cables,* Standards Australia.
- *HB300-2001, Electrical Installations,* Parts 1 and 2, Standards Australia.
- Pethbridge K. and Neeson I., *Electrical Wiring Practice*, Vols 1& 2, 6th Edition, McGraw-Hill, Chapter 15.

Student exercise 9.1 Cable selection based on current

Use AS/NZS 3008.1.1 to determine a suitable conductor size for the following cables in a non-domestic installation:

Consumers main:

Phases:	3
Maximum demand:	155 A
Circuit protection:	Circuit breaker
Cable configuration:	4-core, V90 thermoplastic and sheathed copper conductors
Cable installation:	The circuit is clipped directly to an internal wall with no other circuits and open to the air.

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Sub-main:

Phases:	3
Maximum demand:	75 A
Circuit protection:	Circuit breaker
Cable configuration:	4-core, V90 thermoplastic and sheathed copper conductors
Cable installation:	Secured flat on a single perforated cable tray with two other circuits all touching. The cable tray is suspended 300 mm from the ceiling and is open to the air

Multiple circuits:

De-rating Table No: ____________________

Column No: ____________________

De-rating factor: ____________________

De-rated current capacity: ____________________

Required conductor size:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Student exercise 9.2 Cable selection based on current

Use AS/NZS 3008.1.1 to determine a suitable conductor size for the following cables in a non-domestic installation:

Consumers main:

Phases:	3
Maximum demand:	180 A
Circuit protection:	HRC fuses
Cable configuration:	4 single-core, V90 thermoplastic insulated and sheathed copper conductors
Cable installation:	The circuit is installed in a single rigid thermoplastic conduit, which is clipped directly to an external wall with no other circuits and open to the air.

HRC Fuse protection:

De-rating factor: ______________________________

De-rated current capacity: ______________________________

Required conductor size:

Table No: ______________________________

Column No: ______________________________

Conductor size: ______________________________

Sub-main:

Phases:	3
Maximum demand:	75 A
Circuit protection:	Circuit breaker
Cable configuration:	4-core, non-armoured, V90 insulated and sheathed, circular cable with copper conductors
Cable installation:	Clipped directly to an internal wall with three other circuits all touching, open to the air and protected by circuit breakers

Multiple circuits:

De-rating Table No: ___________________________

Column No: ___________________________

De-rating factor: ___________________________

De-rated current capacity: ___________________________

Required conductor size:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Student exercise 9.3 Cable selection based on current

Use AS/NZS 3008.1.1 to determine a suitable conductor size for the following cables in a non-domestic installation:

Consumers main:

Phases:	3
Maximum demand:	300 A
Circuit protection:	Circuit breaker
Cable configuration:	4 single-core, V90 thermoplastic insulated and sheathed copper conductors
Cable installation:	The circuit is installed in four rigid thermoplastic conduits (one cable per conduit), which are installed in the ground to a depth of 0.5 m and having an ambient soil temperature of 20°C.

Soil temperature:

Re-rating Table No: ____________________

Column No: ____________________

Re-rating factor: ____________________

Re-rated current capacity: ____________________

Required conductor size:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Sub-main:

Phases:	3
Maximum demand:	75 A
Circuit protection:	Circuit breaker
Cable configuration:	4-core, non-armoured, V90 insulated and sheathed, circular cable with copper conductors
Cable installation:	The circuit is installed in rigid thermoplastic conduit with three other circuits separated by 150 mm. Each conduit is installed in the ground to a depth of 0.5 m and having an ambient soil temperature of 20°C

Soil temperature:

Re-rating Table No: ______________________

Column No: ______________________

Re-rating factor: ______________________

Re-rated current capacity: ______________________

Multiple circuits:

Re-rating Table No: ______________________

Column No: ______________________

Re-rating factor: ______________________

Re-rated current capacity: ______________________

Required conductor size:

Table No: ______________________

Column No: ______________________

Conductor size: ______________________

Student exercise 9.4 Determining cable size

1. Determine the conductor size for the sub-main to Unit 4 on the site plan of Figure B2 in Apprendix B of this resource manual. Use the results from Table 6.4 — Single living unit maximum demand detailed in Section 6 of this resource manual to help complete the following details for the installation.

   Sub-main:

   Phases: 1

   Maximum demand: ______________________ A

   Circuit protection: ______________________

   Cable configuration: ______________________

   ____

   Cable installation: ______________________

   ____

   ____

Multiple circuits:

Re-rating Table No: ______________________

Column No: ______________________

Re-rating factor: ______________________

Re-rated current capacity: ______________________

Required conductor size:

Table No: ____________________________

Column No: ____________________________

Conductor size: ____________________________

2. Determine the conductor size for the consumer main for the supply mains to the installation on the site plan of Figure B2 in Appendix B of this resource manual. Use the results from Table 6.2 — Multiple living units and Table 6.3 — Communal load detailed in Section 6 of this resource manual to help complete the following details for the installation.

   Service-main:

   Phases: 3

   Maximum demand: ____________________ A

   Circuit protection: ____________________

   Cable configuration: ____

   ____

   Cable installation: ____

   ____

   ____

   Required conductor size:

   Table No: ____________________________

   Column No: ____________________________

   Conductor size: ____________________________

Student exercise 9.5 Cable size for the installation

1. Complete Table 9.1 for the single domestic installation using the wiring system selected in Exercise 7.2 and detailed in Appendix A.

Table 9.1 Conductor sizes for domestic installation

Circuit	*Installation condition*	*Conductor size*
Service mains		
Lighting		
Socket Outlets		
Cook-top		
Oven		
Water heater		
Air conditioner		

2. Complete Table 9.2 and Table 9.3 for the multiple domestic installation using the wiring system selected in Exercise 7.2 and detailed in Appendix B.

Table 9.2 Conductor sizes for multiple domestic installation

Individual living unit		
Circuit	*Installation condition*	*Conductor size*
Service mains Unit)		
Lighting (Unit)		
Socket Outlets (Unit)		
Cook-top (Unit)		
Oven (Unit)		
Water heater (Unit)		
Air conditioner (Unit)		

Table 9.3 Conductor sizes for multiple domestic installation

Communal load		
Circuit	*Wiring system*	*Reason*
Service mains		
Lighting (Bollards)		
Lighting (barbecue)		
Lighting (Swimming)		

3. Complete Table 9.4 for a non-domestic installation using the wiring system selected in Exercise 7.2 and detailed in Appendix C.

Table 9.4 Conductor sizes for non-domestic installation

Circuit	*Installation condition*	*Conductor size*
Sub mains		
Lighting (office)		
Socket Outlets (office)		
Lighting (factory)		
Socket outlets (office)		
3-phase outlets		
Water heater		

Student exercise 9.6 Calculating per unit voltage drop

1. Calculate the per unit voltage drop in milli-volt per ampere metre for a single living unit (single domestic installation) using the results from Table 6.4 - Single living unit maximum demand detailed in Section 6 of this resource manual.

2. Calculate the per unit voltage drop in milli-volt per ampere metre for a multiple domestic installation using the results from Table 6.2 - Multiple living unit and Table 6.3 - Communal load demand detailed in Section 6 of this resource manual.

Student exercise 9.7 Selection of fault protection for the installation

1. Complete Table 9.5 for the single domestic installation using the wiring system selected in Student Exercise 7.2, Student Exercise 9.5, and detailed in Appendix A.

Circuit	*Installation condition*	*Conductor size*	*Protection type*	*Protection rating*
Service mains				
Lighting				
Socket outlets				
Cook-top				
Oven				
Water heater				
Air conditioner				

2. Complete Table 9.6 and Table 9.7 for the multiple domestic installation using the wiring system selected in Student Exercise 7.2, Student Exercise 9.5, and detailed in Appendix B.

Table 9.6 Fault protection for multiple domestic installation

Circuit	*Installation condition*	*Conductor size*	*Protection type*	*Protection rating*
Sub-mains (Unit)				
Lighting (Unit)				
Socket outlets (Unit)				
Cook-top (Unit)				
Oven (Unit)				
Water heater (Unit)				
Air conditioner (Unit)				

Table 9.7 Fault protection for multiple domestic installation

Circuit	*Installation condition*	*Conductor size*	*Protection type*	*Protection rating*
Service mains				
Lighting (Bollards)				
Lighting (Barbecue)				
Lighting (Swimming)				

3. Complete Table 9.8 for a non-domestic installation using the wiring system selected in Student Exercise 7.2, Student Exercise 9.5, and detailed in Appendix C.

Table 9.8 Fault protection for non-domestic installation

Circuit	*Installation condition*	*Conductor size*
Sub mains		
Lighting (Office)		
Socket outlets (Office)		
Lighting (Factory)		
Socket outlets (Factory)		
3-phase outlets		
Water heater		

Student exercise 9.8 Arrangement of protection for the installation

1. Complete Figure 9.1 for the single domestic installation by drawing all necessary Active, Neutral and Earth connections and using the wiring system selected in Student Exercise 9.7 and detailed in Appendix A. Separate two-pole combination RCD/MCBs protect all light and power circuits.

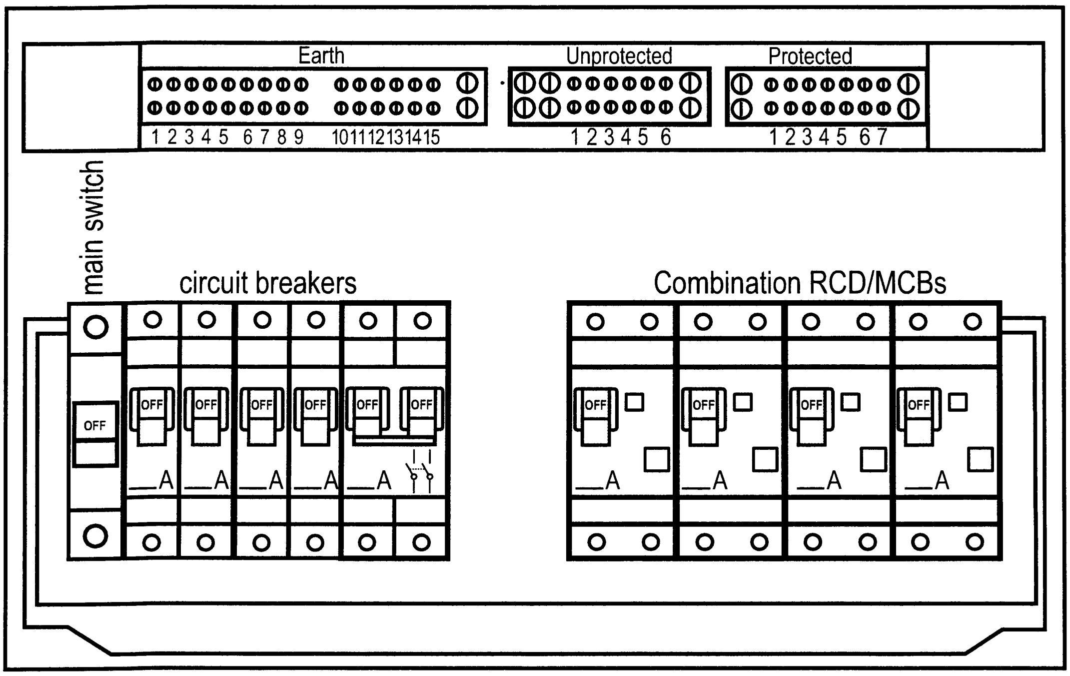


Figure 9.1

Review questions

These questions will help you revise what you have learnt in topic.

Use AS/NZS 3008.1.1 to determine a suitable conductor size for the following installations.

1. The maximum demand current of the consumers mains in a non-domestic installation is calculated to be 290 ampere. The selected cable is 4-core, non-armoured, V90 insulated and sheathed, circular cable with copper conductors. Installation of the cable places it clipped directly to an internal wall, open to the air and protected by circuit breakers.

Table No: ____________________________

Column No: ____________________________

Conductor size: ____________________________

2. The maximum demand current of a sub-mains in a non-domestic installation is calculated to be 120 ampere. The selected cable is 4-core, non-armoured, V90 insulated and sheathed, circular cable with copper conductors. Installation of the cable places it clipped directly to an internal wall with four other circuits all touching, open to the air and protected by circuit breakers.

Multiple circuits:

De-rating Table No: ____________________________

Column No: ____________________________

De-rating factor: ____________________________

De-rated current capacity: ____________________________

Required conductor size:

Table No: ____________________________

Column No: ____________________________

Conductor size: ____________________________

3. The maximum demand current of a sub-mains in a non-domestic installation is calculated to be 80 ampere. The selected cable is 4-core, non-armoured, V90 insulated and sheathed, circular cable with copper conductors. Installation of the cable places it secured flat on a single perforated cable tray with three other circuits all touching. The cable tray is suspended 300 mm from the ceiling, open to the air and the circuit is protected by circuit breakers.

Multiple circuits:

De-rating Table No: ____________________________

Column No: ____________________________

De-rating factor: ____________________________

De-rated current capacity: ____________________________

Required conductor size:

Table No: ____________________________

Column No: ____________________________

Conductor size: ____________________________

4. Two circuits consisting of two-core V90 non-armoured, insulated and sheathed copper conductor cables are clipped, touching in single layer formation, to the underside of a ceiling in a non-domestic installation. Each circuit is to carry 34 A when protected by circuit breakers.

   Multiple circuits:

   De-rating Table No: ____________________________

   Column No: ____________________________

   De-rating factor: ____________________________

   De-rated current capacity: ____________________________

   Required conductor size:

   Table No: ____________________________

   Column No: ____________________________

   Conductor size: ____________________________

5. Four circuits consisting of three-core, V90 circular non-armoured, insulated and sheathed copper conductor cables are bunched together in closed troughing. The troughing is fixed to an internal wall in an horizontal position open to the air. Each circuit is to carry 54 A when protected by circuit breakers.

   Multiple circuits:

   De-rating Table No: ____________________________

   Column No: ____________________________

   De-rating factor: ____________________________

   De-rated current capacity: ____________________________

   Required conductor size:

   Table No: ____________________________

   Column No: ____________________________

   Conductor size: ____________________________

Review questions

6. Three circuits of four-core HFI-90-TP circular thermoplastic insulated and sheathed non-armoured copper conductor cables are buried directly in the ground at a depth of 0.5 m where the ambient soil temperature of 25°C. The cables are spaced at a distance of 150 mm from one another. Each circuit is to carry 125 A when protected by circuit breakers.

Multiple circuits:

De-rating Table No: ____________________

Column No: ____________________

De-rating factor: ____________________

De-rated current capacity: ____________________

Required conductor size:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

7. Two circuits consisting of 3 single-core V90 insulated, unsheathed non-armoured (TPI) copper conductor cables are installed in trefoil formation on a single tier horizontally mounted perforated cable tray. Each trefoil formation touches the other. Each circuit is to carry 41 A when protected by circuit breakers.

Multiple circuits:

De-rating Table No: ____________________

Column No: ____________________

De-rating factor: ____________________

De-rated current capacity: ____________________

Required conductor size:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

8. A single circuit consists of 3 single-core V90 insulated, unsheathed non-armoured (TPI) copper conductor cables enclosed in rigid thermoplastic conduit, which is buried in the ground at a depth of 1.25 m in an ambient soil temperature of 25°C. The circuit is to carry 175 A when protected by circuit breakers.

In-ground:

De-rating Table No: ____________________

Column No: ____________________

De-rating factor: ____________________

De-rated current capacity: ____________________

Required conductor size:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

9. A single 16 mm^2 circular three-core V90 insulated and sheathed non-armoured copper conductor cable is attached to a catenary wire and exposed to the open air. Determine the current carrying capacity of the cable when protected by circuit breakers.

Conductor rating:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

10. Four circuits consist of 35 mm^2 circular two-core V90 insulated and sheathed non-armoured copper cables are installed on a horizontally mounted perforated cable tray. The cable are installed flat, touching on the single tier tray. Determine the current carrying capacity of the cable when protected by circuit breakers.

Basic rating:

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Multiple circuits:

De-rating Table No: ____________________________

Column No: ____________________________

De-rating factor: ____________________________

De-rated current capacity: ____________________________

11. Three circuits consist of 4 mm^2 circular two-core and earth V90 insulated and sheathed non-armoured copper cables are installed bunched on the surface of a plasterboard ceiling in a non-domestic installation. Determine the current carrying capacity of the cable when protected by circuit breakers.

Basic rating:

Table No: ____________________________

Column No: ____________________________

Conductor size: ____________________________

Multiple circuits:

De-rating Table No: ____________________________

Column No: ____________________________

De-rating factor: ____________________________

De-rated current capacity: ____________________________

12. Four circuits consist of 1 mm^2 flat two-core and earth V90 insulated and sheathed non-armoured copper cables are enclosed together in a rigid thermoplastic conduit. The conduit is saddled across ceiling joists and partially surrounded by thermal insulation. Determine the current carrying capacity of the cable when protected by circuit breakers.

Basic rating:

Table No: ____________________________

Column No: ____________________________

Conductor size: ____________________________

Multiple circuits:

De-rating Table No: ____________________________

Column No: ____________________________

De-rating factor: ____________________________

De-rated current capacity: ____________________________

10. Selection of Neutral Conductors

What this topic covers

This topic will provide exercises in the AS/NZS 3008.1.1 and AS/NZS 3000:2000 requirements for the safe selection of cables in electrical installations as a revision and preparation for the Electrical Systems Safety assessment. It covers critical knowledge and skills for the selection of the correct neutral conductor size for three phase circuits.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- selection of neutral cable size based on current-carrying capacity
- producing evidence that cable size complies with safety requirements

Where you will find information

The following references will help you in completing the exercises and review questions in the topic.

- *AS/NZS 3000:2000 Wiring rules,* Section 3, Standards Australia.
- *AS/NZS 3008.1.1 Electrical Installations - Selection of Cables,* Standards Australia.
- *HB300 - 2000, Electrical Installations*, Part 3, Standards Australia.
- Pethbridge K. and Neeson I., *Electrical Wiring Practice K.*, 6th Edition, Vol.2, McGraw-Hill, Sydney, Chapter 15.

Student exercise 10.1 Selection of neutral — single phase load

A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 85 ampere per phase. The greater portion of the maximum demand current consists of single-phase loads (most load devices connect between active and neutral). The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables place them in rigid thermoplastic conduit, clipped directly to an internal wall open to the air and protected by HRC fuses. To determine the minimum conductor size for the neutral, proceed as follows:

1. Determine the size and current carrying capacity of the active conductors.

 Table No: ______________________

 Column No: ______________________

 Conductor size: ______________________

2. Determine the current carrying capacity of the neutral.

 ____

3. Determine the size of the neutral conductor.

 Table No: ______________________

 Column No: ______________________

 Conductor size: ______________________

Student exercise 10.2 Selection of neutral — three phase loads

A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 390 ampere per phase. The greater portion of the maximum demand current is balanced over the three phases. The active conductors are three single-core, non-armoured, V90 insulated and sheathed, circular cable with copper conductors. Installation of the cable places it clipped directly to an internal wall open to the air and protected by circuit breakers. To determine the minimum conductor size for the neutral, proceed as follows:

1. Determine the size and current carrying capacity of the active conductors.

 Table No: ______________________

 Column No: ______________________

 Conductor size: ______________________

2. Determine the current carrying capacity of the neutral.

 ____

3. Determine the size of the neutral conductor.

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Student exercise 10.3 Selection of neutral — single phase loads

A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 185 ampere per phase. The greater portion of the maximum demand current consists of single-phase loads (most load devices connect between active and neutral). The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables place them in rigid thermoplastic conduit, clipped directly to an internal wall open to the air and protected by circuit breakers. Determine the minimum conductor size for the neutral conductor.

1. Determine the size and current carrying capacity of the active conductors.

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

2. Determine the current carrying capacity of the neutral.

____

3. Determine the size of the neutral conductor.

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Student exercise 10.4 Selection of neutral — single phase loads

A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 450 ampere per phase. The greater portion of the maximum demand current consists of single-phase loads (most load devices connect between active and neutral). The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables place them in rigid thermoplastic conduit, clipped directly to an internal wall open to the air and protected by HRC fuses. Determine the minimum conductor size for the neutral conductor.

1. De-rate the maximum demand current for HRC fuse protection

   ____

   ____

2. Determine the size and current carrying capacity of the active conductors

   Table No: ____________________

   Column No: ____________________

   Conductor size: ____________________

3. Determine the current carrying capacity of the neutral

   ____

4. Determine the size of the neutral conductor

   Table No: ____________________

   Column No: ____________________

   Conductor size: ____________________

Student exercise 10.5 Selection of neutral — single phase loads

A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 360 ampere per phase. The greater portion of the maximum demand current is balanced over the three phases. The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables place them in rigid thermoplastic conduit, clipped directly to an internal wall open to the air and protected by circuit breakers. Determine the minimum conductor size for the neutral conductor.

1. Determine the size and current carrying capacity of the active conductors

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

2. Determine the current carrying capacity of the neutral

____

3. Determine the size of the neutral conductor

Table No: ____________________

Column No: ____________________

Conductor size: ____________________

Review questions

These questions will help you revise what you have learnt in this topic.

1. A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 180 ampere per phase. The greater portion of the maximum demand current is balanced over the three phases. The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables places them in rigid thermoplastic conduit, buried in the ground at a depth of 500 mm where the ambient soil temperature is 25°C. The cables are protected by circuit breakers. Determine the minimum conductor size for the neutral conductor.

   Determine the size and current carrying capacity of the active conductors

2. A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 455 ampere per phase. The greater portion of the maximum demand current consists of single-phase loads (most load devices connect between active and neutral). The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables places them in rigid thermoplastic conduit, buried in the ground at a depth of 500mm where the ambient soil temperature is 25°C. HRC fuses protect the cables. Determine the minimum conductor size for the neutral conductor.

   De-rate the maximum demand current for HRC fuse protection

3. A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 150 ampere per phase. The greater portion of the maximum demand current consists of single-phase loads (most load devices connect between active and neutral). The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables place them in rigid thermoplastic conduit, clipped directly to an internal wall open to the air and protected by HRC fuses. Determine the minimum conductor size for the neutral conductor.

   De-rate the maximum demand current for HRC fuse protection

4. A factory installation has a three-phase 400-volt supply, which has a multiple earthed neutral connection. The maximum demand current of the installation is calculated at 85 ampere per phase. The greater portion of the maximum demand current consists of single-phase loads (most load devices connect between active and neutral). The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables place them in rigid thermoplastic conduit, clipped directly to an internal wall open to the air and protected by circuit breakers. Determine the minimum conductor size for the neutral conductor.

   Determine the size and current carrying capacity of the active conductors

11. Fault-Loop Impedance

What this topic covers

This topic will provide exercises in the AS/NZS 3000: 2000 requirements for the safe selection of electrical equipment in electrical installations as a revision and preparation for the Electrical Systems Safety assessment. It covers parts of the critical knowledge and skills for ensuring circuits meet fault loop impedance requirements.

Demonstrate knowledge and skill related to

Demonstrate knowledge and skills related to:

- the selection of cable size based on fault-loop impedance limitations
- determining compliance of fault-loop impedance
- producing evidence that electrical equipment complies with safety requirements
- identifying actions or conditions that would void the compliant status of given items of electrical equipment.

Where you will find information

The following references will help you in completing the exercises and review questions in the topic.

- *AS/NZS 3000:2000 Wiring rules*, Sections 1, 6 and Appendix B, Standards Australia.
- *HB300 - 2001 Electrical Installations*, Part 2, Standards Australia.
- Pethebridge K. and Neeson I., *Electrical Wiring Practice*, 6th Ed., Vol.2, McGraw-Hill, Sydney, Chapter 15.

Student exercise 11.1 Fault-loop impedance

A final sub-circuit supplies a load consisting of 10 A socket outlets and is protected by a 20 A type C circuit breaker. Determine the maximum internal fault-loop impedance of the final sub-circuit, based on 230 V, when supply is unavailable:

Student exercise 11.2 Fault-loop impedance

A final sub-circuit supplies a load consisting of 10 A socket outlets and is protected by a 16 A type C circuit breaker. The internal fault-loop is impedance, measured at the furthermost socket outlet is 1.2 Ω. Determine whether this value of internal fault-loop impedance, based on 230 V, satisfies the requirements of AS/NZS 3000:2000.

Student exercise 11.3 Fault-loop impedance

A final sub-circuit supplies a load consisting of fluorescent luminaires in a non-domestic installation. A 10 A type C circuit breaker protects the circuit. The internal fault-loop impedance, measured at the furthermost luminaire is 1.15 Ω. Determine whether this value of internal fault-loop impedance, based on 230 V, satisfies the requirements of AS/NZS 3000:2000.

Review questions

These questions will help you revise what you have learnt in this topic.

1. A final sub-circuit supplies a load consisting of a range in a domestic installation and is protected by a 32 A type C circuit breaker. Determine the maximum internal fault-loop impedance of the final sub-circuit, based on 230 V, when supply is unavailable:

2. A final sub-circuit supplies a load consisting of fluorescent luminaires and is protected by a 10 A type C circuit breaker. Determine the maximum internal fault-loop impedance of the final sub-circuit, based on 230 V, when supply is unavailable:

3. A final sub-circuit supplies a load consisting of 10 A socket outlets and is protected by a 20 A type C circuit breaker. Determine the maximum internal fault-loop impedance of the final sub-circuit, based on 240 V, when supply is unavailable:

4. A final sub-circuit supplies a load consisting of 15 A socket outlets and is protected by a 25 A HRC fuse. Determine the maximum internal fault-loop impedance of the final sub-circuit, based on 230 V, when supply is unavailable:

5. Explain in point form a suitable procedure for measuring the fault-loop impedance of a new final sub-circuit supplying sixteen 10 A-socket outlets in a domestic installation where power is not yet available.

6. Use arrows to indicate the fault-loop path on the diagram of Figure 11.1 if a fault were to occur between the active terminal of the appliance and the frame of the appliance.

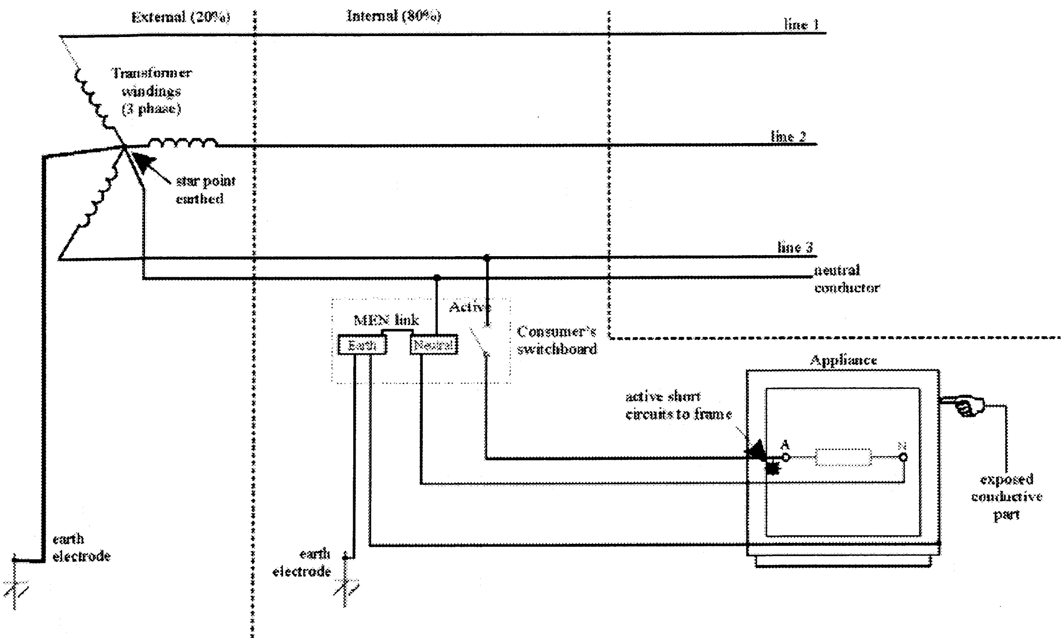


Figure 11.1

Notes

12. Installation Inspection and Testing

What this topic covers

This topic will provide exercises in the AS/NZS 3000: 2000 requirements for safety testing of electrical installations as a revision and preparation for the Electrical Systems Safety assessment. It covers parts of the critical knowledge and skills for ensuring that electrical installations pass all inspection tests.

What you are expected to be able to do

Demonstrate knowledge and skills related to:

- detail the mandatory tests
- identify non-compliance from given test results
- make recommendations to rectify cause of non-compliance
- complete mandatory documentation.

Where you will find information

The following references will help you in completing the exercises and review questions in the topic.

- *AS/NZS 3000:2000 Wiring rules,* Sections 6, Standards Australia.
- *AS/NZS 3017:2001 Electrical Installations - Testing,* Standards Australia.
- *HB300 - 2001 Electrical Installations,* Part 4, Standards Australia.
- Pethebridge K. and Neeson I., *Electrical Wiring Practice*, 6th Ed., Vol. 2, McGraw-Hill, Sydney, Chapter 11.

Student exercise 12.1 Visual inspection

Under each of the given headings document items to check during a visual inspection to ensure the installation meets the requirements specified in *AS/NZS 3000:2000*.

General:

Consumer mains:

Switchboards:

Wiring systems:

Electrical equipment:

Earthing:

Student exercise 12.2 Resistance of earthing conductors

Student exercise 12.2 Resistance of earthing conductors

- Draw the circuit arrangement for performing the test in Figure 12.1.
- List the required equipment, outline test procedure and document acceptable results for earthing conductors resistance test on an installation.

Circuit arrangement:

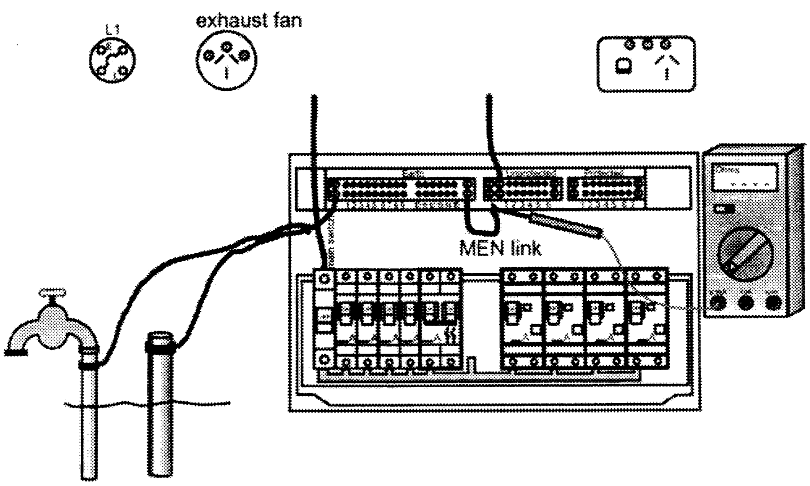


Figure 12.1 Measuring resistance of earthing conductors

Equipment:

Procedure:

Result:

Student exercise 12.3 Insulation resistance of final sub-circuits

- Draw the circuit arrangement for performing the test in Figure 12.2.
- List the required equipment, outline test procedure and document acceptable results for insulation resistance test on an installation.

Circuit arrangement:

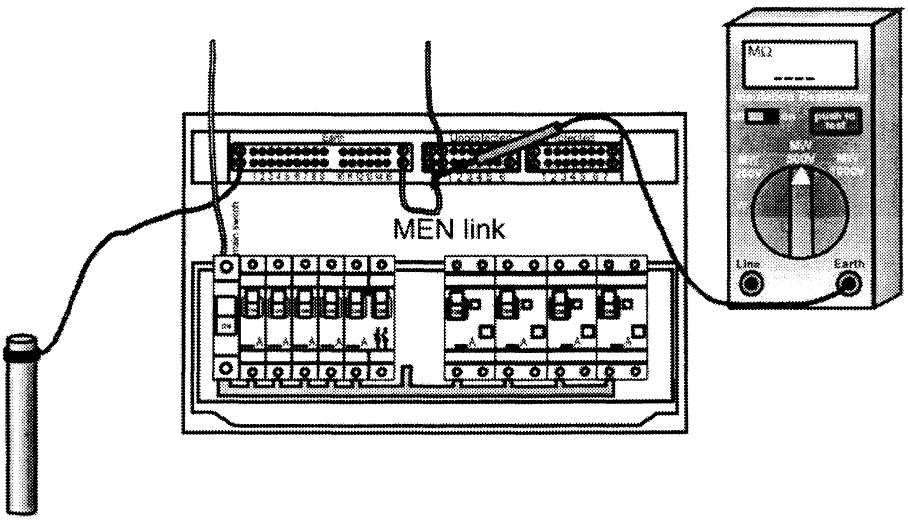


Figure 12.2 Measuring insulation resistance of final sub-circuits

Equipment:

Procedure:

Result:

Student exercise 12.4 Polarity testing consumer mains

- Draw the circuit arrangement for performing the test in Figure 12.3.
- List the required equipment, outline test procedure and document acceptable results for testing the polarity of consumers mains on an installation.

Circuit arrangement:

Figure 12.3 Polarity testing of consumer mains

Equipment:

Procedure:

Result:

Student exercise 12.5 Polarity testing sub-mains

- Draw the circuit arrangement for performing the test in Figure 12.4.
- List the required equipment, outline test procedure and document acceptable results for testing the polarity of sub-mains on an installation.

Circuit arrangement:

Figure 12.4 Polarity testing of sub-mains

Equipment:

Procedure:

Result:

Student exercise 12.6 Polarity testing final sub-circuits

- Draw the circuit arrangement for performing the test in Figure 12.5.
- List the required equipment, outline test procedure and document acceptable results for testing the polarity of sub-circuits on an installation.

Circuit arrangement:

Figure 12.5 Polarity testing of final sub-circuits

Equipment:

Procedure:

Result:

Student exercise 12.7 Completing notification form

1. Obtain the relevant notification form from your local supply authority.
2. Complete the form for a new installation to the required specification using the following information.

Customer:

Ted E Bear,

22 Honeysuckle Drive,

Bearsville. 2299.

Electrical contractor

TAF Electrical Services,

12 Spring Avenue,

Springfield. 2288.

Installing electrician:

Your name

Supply authority:

Your local supply authority

Installation details:

6 only 50 W 12 V down light

10 only 60 W 230 V light point

5 only 18 W 230 V round fluorescent luminaire

6 only single 10 A socket outlet

15 only double 10 A socket outlet

1 only 14.5 A split system air conditioner

1 only 9.6 kW upright range

1 only 4.6 kW off-peak hot water service

Consumer mains:

Four by 16 mm^2 SDI

Main earth electrode:

Directly below switchboard

Water service equipotential bond:

At water pipe entry at front of building on switchboard side of building

Test results:

Insulation resistance:

Water heater	3.0 MΩ
Range	0.4 MΩ
Other circuits	Infinity

Earth continuity:

Main earth	0.1 Ω
Equipotential bond	0.15 Ω
All other	<0.8 Ω

All other tests:

Correct

Student exercise 12.8 Installation defects 1

Figure 12.6 shows the arrangement of the main switchboard for part of a new 230 V, MEN domestic installation having a calculated maximum demand of 35 A.

HRC fuses protect both final sub-circuits, which comprise V90 insulated copper conductor cables. Installation of the cables makes them unenclosed, in air, and in single circuit configuration. The switchboard has other final subcircuits, which for clarity are not shown.

Carefully consider Figure 12.6 and in the space provided in Table 12.1, write details of the defect (breach of AS/NZS 3000:2000) and state the specific Clause or Table number contravened. State also the remedial action required. The first defect is provided by way of example.

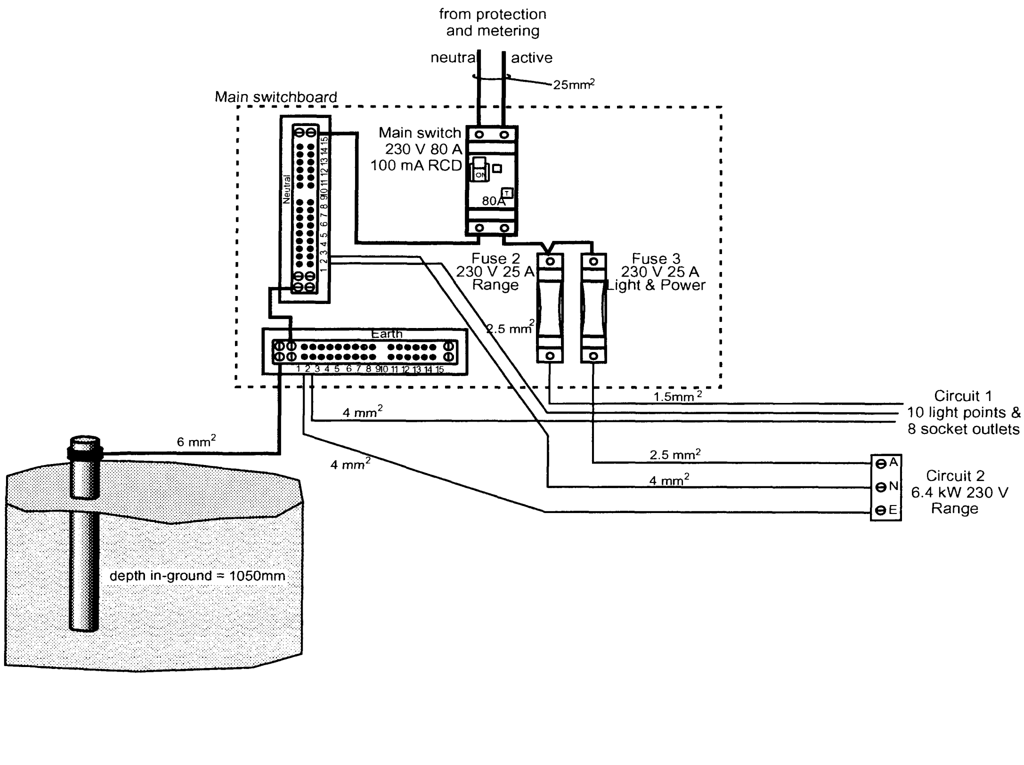


Figure 12.6 Details of Exercise 12.7

Result

Table 12.1

	Defect	*Clause or Table No*	*Remedial action*
1.	Earth electrode driven to depth of 1050 mm. Minimum required is 1200 mm	Clause 5.6.2.2	Drive electrode a further 150 mm into ground
2.			
3.			
4.			
5.			

Student exercise 12.9 Installation defects 2

Figure 12.7 shows the arrangement of the main switchboard for part of a new 240 V, MEN commercial installation having a calculated maximum demand of 30 A.

A circuit breaker protects the final sub-circuit; comprising single core V75 insulated copper conductor cables. Installation of the cables makes them enclosed, in air, and in single circuit configuration. The switchboard has other final subcircuits, which for clarity are not shown.

Carefully consider Figure 12.7 and in the space provided in Table 12.2, write details of the defect (breach of AS/NZS 3000:2000) and state the specific Clause or Table number contravened. State also the remedial action required. The first defect is provided by way of example.

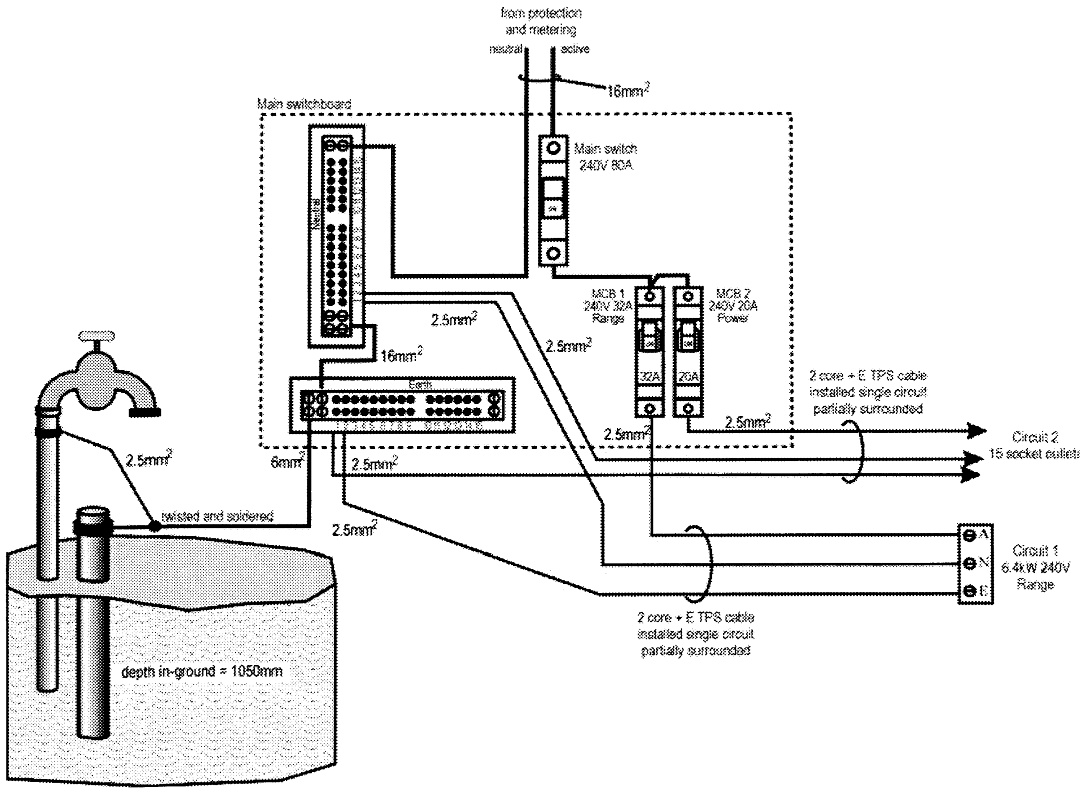


Figure 12.7 Details of Exercise 12.9

Result

Table 12.2

	Defect	*Clause or Table No*	*Remedial action*
1.	Earth electrode driven to depth of 1050 mm. Minimum required is 1200 mm	Clause 5.6.2.2	Drive electrode a further 150 mm into ground
2.			
3.			
4.			
5.			

Student exercise 12.10   Installation defects 3

Figure 12.8 shows the arrangement of the main switchboard for part of a new 230 V, MEN domestic installation having a calculated maximum demand of 53 A.

A circuit breaker protects the final sub-circuit; comprising single core V90 insulated copper conductor cables. Figure 12.8 details the installation method for the cables. The switchboard has other final subcircuits, which for clarity are not shown.

Carefully consider Figure 12.8 and in the space provided in Table 12.3, write details of the defect (breach of AS/NZS 3000:2000) and state the specific Clause or Table number contravened. State also the remedial action required. The first defect is provided by way of example.

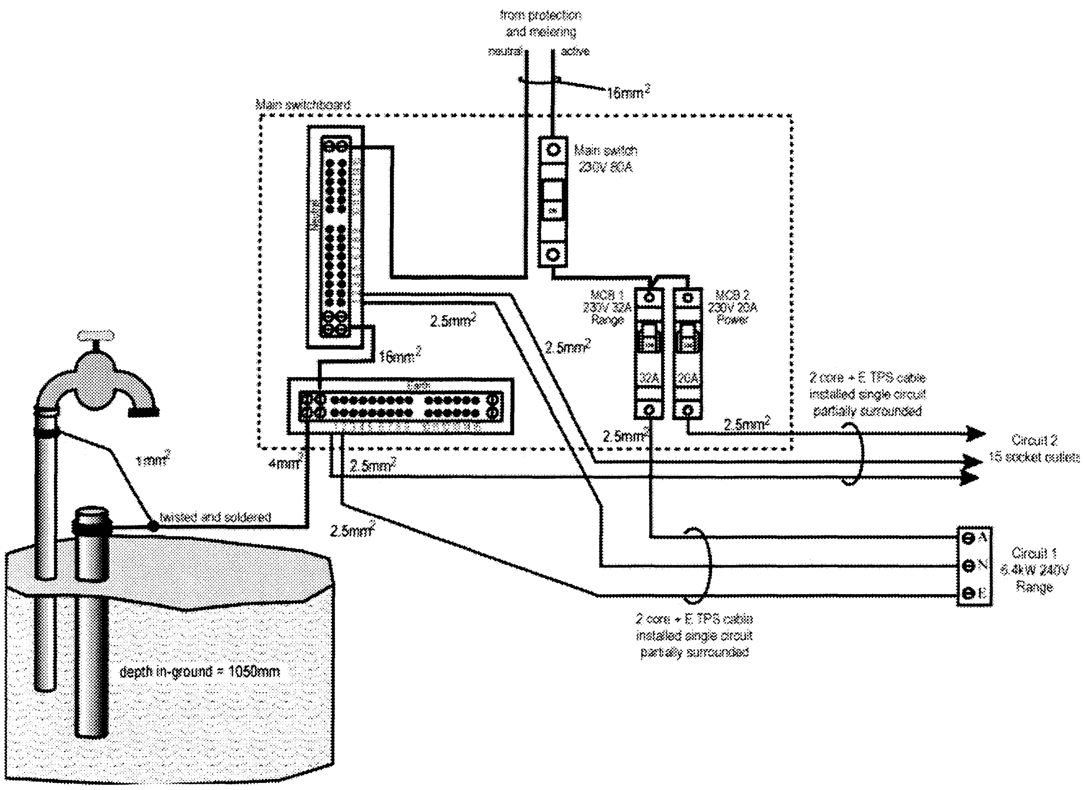


Figure 12.8 Details of Exercise 12.10

Result

Table 12.3

	Defect	*Clause or Table No*	*Remedial action*
1.	Earth electrode driven to depth of 1050 mm. Minimum required is 1200 mm	Clause 5.6.2.2	Drive electrode a further 150 mm into ground
2.			
3.			
4.			
5.			

Student exercise 12.11 Installation defects 4

Figure 12.9 shows the arrangement of the main switchboard for part of a new 400 V, MEN domestic installation having a calculated maximum demand of 65 A.

Circuit breakers protect all final sub-circuits; comprising single core V90 insulated copper conductor cables. Figure 12.9 details the installation method for the cables. The switchboard has other final subcircuits, which for clarity are not shown.

Carefully consider Figure 12.9 and in the space provided in Table 12.4, write details of the defect (breach of AS/NZS 3000:2000) and state the specific Clause or Table number contravened. State also the remedial action required. The first defect is provided by way of example.

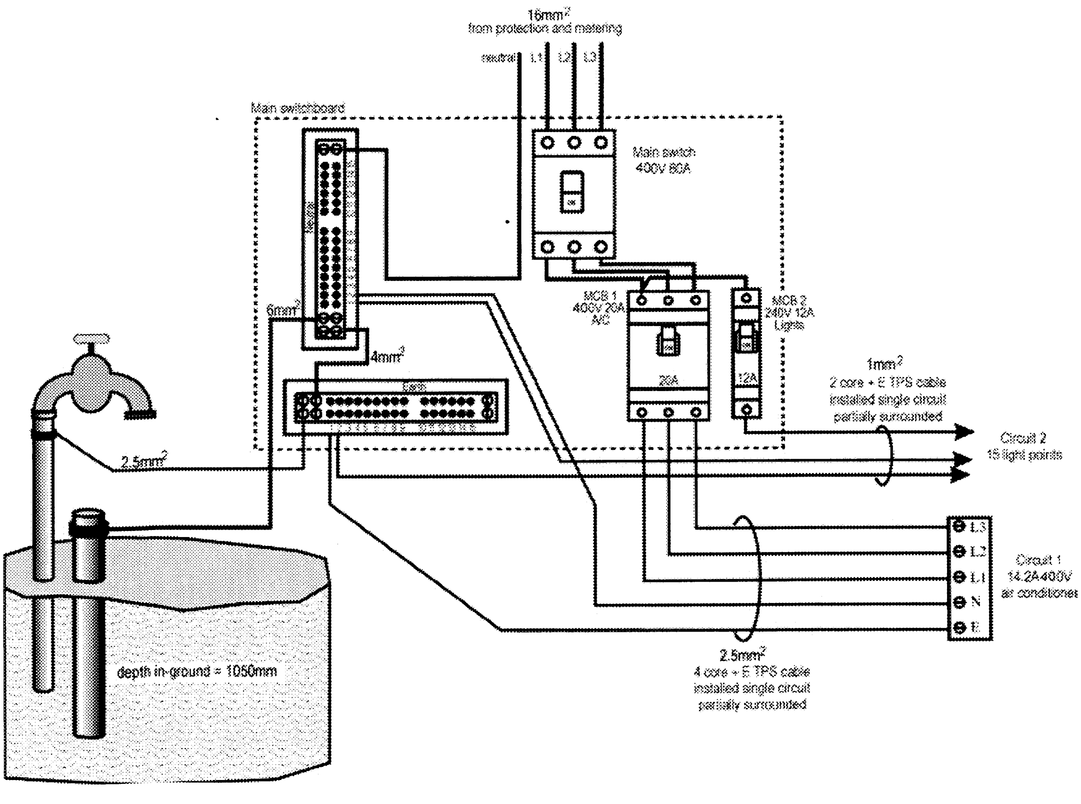


Figure 12.9 Details of Exercise 12.11

Result

Table 12.4

	Defect	*Clause or Table No*	*Remedial action*
1.	Earth electrode driven to depth of 1050 mm. Minimum required is 1200 mm	Clause 5.6.2.2	Drive electrode a further 150 mm into ground
2.			
3.			
4.			
5.			

Review questions

These questions will help you revise what you have learnt in this topic.

1. The minimum insulation resistance for a final sub-circuit in an installation is:
   (A) not less than 0.01 MΩ
   (B) not less than 0.5 Ω
   (C) not less than 1 MΩ
   (D) not less than 5 MΩ.

2. The expected resistance measured between active and neutral for a final sub-circuit supplying a 4.8 kW hot water service is:
   (A) 0.5 Ω
   (B) 12 Ω
   (C) 20 Ω
   (D) 1MΩ.

3. The voltage used to perform an insulation resistance test on a final sub-circuit on a 230/400 volt installation is:
   (A) 250 V a.c.
   (B) 250 V d.c.
   (C) 500 V a.c.
   (D) 500 V d.c
   (E) 1000 V a.c.
   (F) 1000 V d.c.

4. The resistance of protective earthing conductors is specified in AS/NZS 3000 as being:
   (A) not more than 2 Ω
   (B) not more than 0.5 Ω
   (C) greater than 1 MΩ
   (D) low enough for correct operation of protective device.

5. Before performing an insulation resistance test on a final sub-circuit, which is supplying socket outlets, it is necessary to:
   (A) plug in all appliances and turn socket outlet on
   (B) plug in all appliances and turn socket outlet off
   (C) all appliances are disconnected from the socket outlets
   (D) test all appliances separately in accordance with AS/NZS 3000.

6. It is necessary to test consumer mains in a new installation for:
   (A) insulation resistance before connection of supply
   (B) insulation resistance and fault-loop impedance before connection of supply
   (C) polarity and switchboard colour coding before connection of supply
   (D) insulation resistance and polarity before connection of supply.

7. The most appropriate method of verifying that there is no transposition of neutral and earth conductors supplying a hot water service is to:
   (A) test for insulation resistance
   (B) carry out a visual inspection of the circuit
   (C) test for earth continuity of the main earth conductor
   (D) measure the resistance between final sub-circuit active and neutral with earth disconnected.

8. Adequate insulation resistance helps to ensure:
   (A) earthing continuity
   (B) active and neutral continuity
   (C) protection against direct contact with live parts
   (D) protection against mechanical damage of conductors.

Review Questions - Answers

1. Working safely

1. It is important for both lamps to have the same power and voltage rating.

2. 240 V, 15W.

3. Does not trip residual current devices when testing between active and earth.

4. Lock-out and fit a danger tag.

5. 50 mA

6. Current path through body, magnitude of current and duration.

7. To provide a warning to others.

8. If connected to active first the floating lead is live.

9. Series test lamps, voltage probe and voltmeter.

2. Protection for safety

1. Insulation; Barriers or enclosures; Obstacles; Placing out of reach.
   (reference clause 1.7.3.2)

2. Completely covered with insulation capable of withstanding mechanical, chemical, electrical and thermal influences to which may be subjected.
   (reference clause 1.7.3.3)

3. IPXXB or IP2X and IPXXD or IP4X for horizontal top surfaces that are readily accessible.
   (reference clause 1.7.3.4.1)

4. Take precautions to prevent persons or livestock from unintentionally touching live parts and persons advised that live parts can be touched through the opening.
   (reference clause 1.7.3.4.1)

5. Use of tool or key required
   Interlocking device fitted which switches off supply
   Intermediate barrier protection provided
   (reference clause 1.7.3.4.2)

6. See clause 1.4.12

7. Prevent fault current passing through body.
Limit fault current which can pass through body to a lower value.
Automatically disconnect supply of fault.
(reference clause 1.7.4.1)

8. 0.4 second (reference clause 1.7.4.3.4)

9. Screen flammable materials.
Enclose electrical equipment likely to produce arcs.
(reference clause 1.7.6)

10. Segregation and devices that protect against transient voltages.
(reference clause 1.7.10)

3. Earthing system

1. (C) 10 mm^2 Reference AS/NZS 3000 clause 5.5.1(c)

2. (B) 1.0 mm^2 Reference AS/NZS 3000 clause 5.5.1(e)

3. (B) 1.0 mm^2 Reference AS/NZS 3000 clause 5.5.1(e)

4. (B) 120 mm^2 Reference AS/NZS 3000 clause 5.5.1.3

5. (A) 0.5 Ω Reference AS/NZS 3000 clause 1.11.2

6. (B) The difference of potential between simultaneously accessible parts.
Reference AS/NZS 3000 clause 1.4.87

7. (C) Equipment complying with AS/NZS 3100 for double insulation.
Reference AS/NZS 3000 clause 5.4.1

8. (D) May be earthed by a separate MEN installation.
Reference AS/NZS 3000 clause 5.6.6

9. Direct earthing system is not connected to the supply neutral.

10. 162 V.

4. Protection methods and devices

1. (B) Electrical cables.

2. (D) 225% of its original value.

3. (C) 0.9

4. (D) A short circuit.

5. (B) The HRC fuse extinguishes the arcing at the eutectic point.

6. (A) The circuit protective device closest to the fault or over-current should operate before any upstream devices.

7. (A) Cannot be held on while a fault exists.

8. (C) 1.45 times the nominal breaker rating.

9. (C) Magnetic circuit breaker.

10. (B) HRC fuse.

11. (B) 30 mA

12. (B) A trip current of 30 mA and a rated switching current of not less than the installation maximum demand.

13. (B) Light and power circuit.

14. (D) Residual current device.

15. (B) 30 mA

16. See Clause 1.4.36

17. See Clause 1.4.35

18. See Clause 1.4.34

19. See Clause 1.4.55

20 See Clause 1.4.24

21. Prospective fault current is the highest value of current available at the point of installation of the protection device.

22. Inverse current time characteristic means the tripping time of a circuit protection devise is quicker for higher values of current and slower for lower values of current.

23. Excess current in a circuit may be caused by overloads or short circuits.

24. The high value of energy dissipated while the fault exists might cause excessive and destructive damage to wiring and equipment. Also, the associated heating and arcing presents a high fire risk and a person working close to an arc produced in a high-energy situation could sustain a fatal injury.

25. The HRC fuse has a fuse element made of silver inside a barrel made from a strong ceramic material that is a good conductor of heat. The barrel contains a fine grade of sand.

26. Arc extinction relies on the fact that the arc drawn between the contacts is a current carrying conductor and as such, surrounded by a magnetic field the strength of which is proportional to the magnitude of the current. The arc forms between U-shaped metal plates, which distort the circular field around the arc and the resultant magnetic field act on the arc to push it into the plates, which cut the arc into a number of small sections. The cooling effect of the plates and the lengthening and cutting of the arc cause its rapid extinction.

27.

Fault level at point of supply	= 45 kA
Impedance of 35 m of 95 mm^2 cable (from Table 4.1)	= 0.007 Ω
Fault level at DB1 (from Figure 4.8)	= 21 kA
Impedance of 30 m of 35 mm^2 cable (from Table 4.1)	= 0.015 Ω
Fault level at DB2 (from Figure 4.8) is estimated at	= **10 kA**.

28. Teacher to assess this question

5. Switchgear and control gear

1. (D) Motor will reverse direction of rotation.

2. (A) Power factor increases.

3. (C) The starting torque is reduced.

4. (D) 6.

5. (C) Star configuration across the rotor slip rings.

6. See Clause 4.3.4.1

7. See Clause 4.2.1.2

8. See Clause 4.2.1.1

9. See Clause 2.8.4.1

10. I_{start} = 26.7 A, T_{start} = 20 Nm

11. I_{start} = 68.6 A, T_{start} = 147 Nm

12. Starting current must not exceed 201.5 A.
Suitable starters include 70% tap auto-transformer.
Starter and star-delta starter.

6. Electrical Installation design - maximum demand

1.	Table C1	Column 2	Load group Ai	Demand 5 A
2.	Table C1	Column 2	Load group Aii	Demand 5.6 A
3.	Table C1	Column 2	Load group C	Demand 23.9 A
4.	Table C1	Column 2	Load group G	Demand 15 A
5.	Table C2	Column 3	Load group A	Demand 26 A
6.	Table C2	Column 3	Load group A	Demand 10 A
7.	Table C2	Column 3	Load group C	Demand 40 A
8.	Table C2		Load group E	Demand 18.8 A
9.	Table C2		Load group J	Demand 10 A

10.	A	Lighting	11 x 0.35	3.9 A
	B	Power	(1000 +(11 x 750))/240	38.5 A
	D	Motor 1		18.0 A
	D	Motors 2 & 3	(0.75 x 8) + (0.5 x 8)	10.0 A
				70.4 A

11. Table C1 Column 4

Ai	Lighting	5 + (7 x 0.25)	6.75 A
Bi	Power	15 + (7 x 3.75)	41.25 A
D	a/c	7 x (18 x 0.75)	94.5 A
C	Range	7 x 2.8	19.6 A
F	HWS	7 x 6	42.0 A
			204 A

7. Electrical installation design - circuit arrangement

Teacher to assess this sections as justification of selection is required.

8. Electrical installation design - voltage drop

1. Table 41 mV/A.m rating 4.85 Cable size 10 mm^2

2. Table 41 mV/A.m rating 11.0 Cable size 4 mm^2

3. Table 40 mV/A.m rating 6.81 length 3 m

4. Table 42 mV/A.m rating 6.39 Cable size 10 mm^2

5.

Consumer main	Table 41	Volt drop 2.87V	1.66 V (single phase)
Sub-main	Table 40	Volt drop 5.0V	2.89 V (single phase)
Final sub-circuit	Table 42	Volt drop 7.14 V	8.25 V (single phase)
		Total % volt drop	**12.8 V**

9. Selection of cables and protective devices

1. Table 12 Column 4 Conductor size 185 mm^2

2. De-rate Table 22 Column 8 Factor 0.73 De-rated capacity 164 A
   Table 12 Column 4 Conductor size 70 mm^2

3. De-rate Table 24 Column 8 Factor 0.78 De-rated capacity 103 A
   Table 12 Column 2 Conductor size 35 mm^2

4. De-rate Table 22 Column 5 Factor 0.81 De-rated capacity 42 A
   Table 9 Column 4 Conductor size 6 mm^2

5. De-rate Table 22 Column 7 Factor 0.65 De-rated capacity 83 A
   Table 12 Column 6 Conductor size 35 mm^2

6. De-rate Table 25(2) Column 3 Factor 0.78 De-rated capacity 160 A
   Table 12 Column 14 Conductor size 50 mm^2

7.	De-rate	Table 23	Column 7	Factor 0.89	De-rated capacity 46 A
	Table 6	Column 4	Conductor size 10 mm^2		

8.	De-rate	Table 28(2)	Column 2	Factor 0.9	De-rated capacity 194 A
	Table 6	Column 16	Conductor size 95 mm^2		
9.	Table 12	Column 2	Current capacity 72 A		
10.	Table 9	Column 2	Current capacity 140 A		
	De-rate	Table 24	Column 8	Factor 0.78	De-rated capacity 109 A
11.	Table 9	Column 4	Current capacity 34 A		
	De-rate	Table 22	Column 6	Factor 0.70	De-rated capacity 23.8 A
12.	Table 9	Column 10	Current capacity 10 A		
	De-rate	Table 22	Column 7	Factor 0.65	De-rated capacity 6.5 A

10. Selection of neutral conductors

1. Table 6 Column 16 Conductor size 70 mm^2 Current rating 185 A
   Current rating of neutral 61 A
   Table 6 Column 16 Conductor size for neutral 10 mm^2

2. Table 6 Column 16 Conductor size 400 mm^2 Current rating 510 A
   Current rating of neutral 255 A
   Table 6 Column 16 Conductor size for neutral 120 mm^2

3. Table 6 Column 8 Conductor size 95 mm^2 Current rating 166.5 A
   Current rating of neutral 100 A
   Table 6 Column 8 Conductor size for neutral 35 mm^2

4. Table 6 Column 8 Conductor size 25 mm^2 Current rating 87 A
   Current rating of neutral 87 A
   Table 6 Column 8 Conductor size for neutral 25 mm^2

11. Fault-loop impedance

1. 0.768 Ohm

2. 2.46 Ohm

3. 1.28 Ohm

4. 1.31 Ohm

5. Switch circuit breaker of final sub-circuit under test to OFF position.

Use a short length of conductor to bridge between the final sub-circuit active conductor downstream of the circuit protection device and the earth bar.

Locate the furthermost socket outlet installed on the final sub-circuit.

Use a low-reading ohmmeter to measure the resistance between the active terminal, with the switch on the socket outlet in the ON position, and the earth terminal of the selected socket outlet.

Use Table B4.1 of AS/NZS 3000:2000 to determine the maximum fault-loop impedance for a circuit breaker.

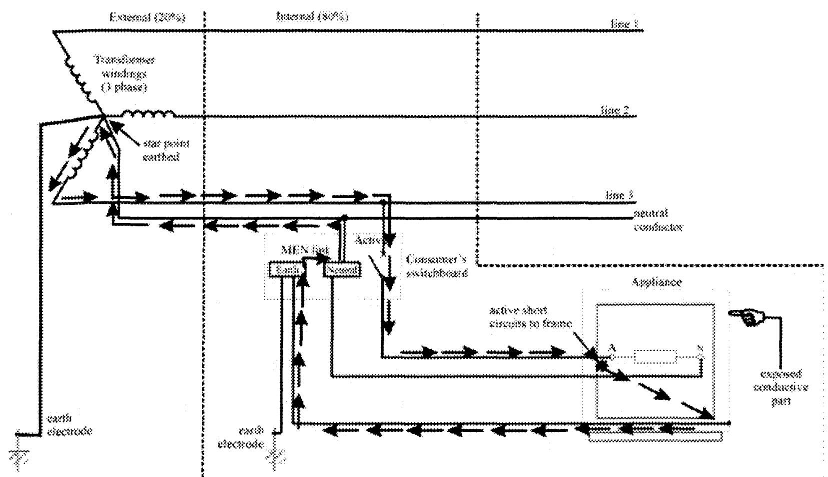
As the fault-loop circuit we are considering is within the customer's installation, 80 per cent of the value obtained from Table B4.1 is considered as the maximum fault-loop impedance for the circuit under test.

In this example the measured fault-loop impedance of 0.75Ω is less than the maximum fault-loop impedance of 1.54Ω, as calculated in Step 6, and is therefor acceptable

If the value measured in Step 4 is higher than the maximum permissible value for fault-loop impedance calculated in Step 6 it is necessary to take action to rectify the cause of high impedance.

Remove the temporary bridging conductor from between the final sub-circuit active conductor downstream of the circuit protection device and the earth bar.

6.



12. Installation inspection and testing

1. (C) Not less than 1 MΩ

2. (B) 12 Ω

3. (D) 500 V d.c

4. (D) Low enough for correct operation of protective device.

5. (C) All appliances are disconnected from the socket outlets.

6. (D) Insulation resistance and polarity before connection of supply.

7. (D) Measure the resistance between final sub-circuit active and neutral with earth disconnected.

8. (C) Protection against direct contact with live parts.

Notes

Sample Assessments

Test 1 - Knowledge

Student equipment required

- AS/NZS 3000:2000 Wiring Rules with amendments and marginal notes
- AS/NZS 3008.1.1:1998 Electrical installation - Selection of cables
- AS/NZS 3017:2001 Electrical installations - Testing and inspection guidelines
- Non-programmable calculators

Section A

Select the best answer for the following statements. Some answers require you to include relevant Standard, Clause, Paragraph and Table Numbers in your answer.

1. Underground cabling, comprising TPS cables enclosed in heavy duty PVC conduit is called a:
   (A) category A underground wiring system
   (B) category B underground wiring system
   (C) category C underground wiring system
   (D) category D underground wiring system.

2. What is the term used to describe the maximum value of current that may flow in an electrical system during a short-circuit?
   (A) let through value of current
   (B) prospective fault current
   (C) cut-off current
   (D) trip or flusing current.

3. The location of a main switchboard in single domestic installation with a maximum demand of less than 100 amperes per phase is determined by:
   (A) the availability of water piping for the main earth
   (B) the height of the building above ground level
   (C) requirements of the Wiring Rules and local Service Rules
   (D) requirements of local Service and Installation Rules.

4. What does the term "touch voltage" mean?
   (A) the voltage which can be accessed by a standard test finger
   (B) the voltage between live conductors and earth
   (C) the votlage between simultaneously accessible parts
   (D) the voltage which can be touched when standing on a conductive surface.

5. Safety at work is the responsibility of:
   (A) employers and their employees
   (B) owners and employer
   (C) owner/controller of a work site
   (D) owner/controller of a work site and employers and their employees.

6. Class I portable equipment should:
   (A) be supplied from a circuit protected by an RCD
   (B) be supplied at extra low voltage
   (C) not be used on construction sites
   (D) not be earthed.

7. In a clearance to work system:
   (A) work must be carried out under direct supervision
   (B) completion of work must be signed-off by the person who did the work
   (C) completion of work must be signed-off by the work supervisor only
   (D) work must be carried out by a tradesperson.

8. The resistance of protection earthing conductors is specified by the Wiring rules as:
   (A) not more than 2 Ω
   (B) not more than 0.5 Ω
   (C) greater than 1 W
   (D) low enough for correct operation of the protective device.

9. What is the maximum disconnection time specified in AS/NZS 3000 for circuits?
   (A) 30 ms for circuits supplying socket outlets and 100 ms for sub-mains
   (B) 30 ms for circuits supplying socket outlets and lights
   (C) 0.4s for circuits supplying portable equipment and 5s for circuits supplying fixed appliances
   (D) 5s for circuits supplying socket outlets and 30s for circuits supplying fixed appliances and sub-mains.

10. Equipment used in an electrical installation shall:
    (A) be rated for 230 V, 50 Hz
    (B) carry the EMI compliant mark
    (C) be safe to use and not cause danger
    (D) carry the Regulatory Compliant Mark.

11. Which of the following protection devices is best suited for quick disconnection of a fault current?
    (A) a residual current device
    (B) a rewireable fuse
    (C) a HRC fuse
    (D) a thermal circuit breaker.

12. A major hazard with confined spaces is:
    (A) not enough room to stand
    (B) difficulty in using tools
    (C) flammable contaminates and oxygen depletion
    (D) only space for one person at a time.

13. The requirements of the Wiring rules that apply to the relocating of existing equipment in an installation using existing conductors are:
    (A) mechanical protection for the cables and fixing and location of the equipment
    (B) fixing and location of the equipment and rating of short circuit protective devices
    (C) fixing and location of the equipment and rating of overload protective devices
    (D) mechanical protection for the cables and rating of overcurrent protective devices.

14. What is the maximum circuit length of a final sub-circuit consisting of 4 mm^2 active and neutral conductors with a 2.5 mm^2 earth conductor when protected by a 32 A type C circuit breaker and having a nominal supply of 230 V?
    (A) 31 m
    (B) 52 m
    (C) 67 m
    (D) 98 m.

15. A final sub-circuit in a domestic kitchen supplies a single-phase 6.4 kW oven. What is a suitable rating for cable supplying the oven?
    (A) 8 A
    (B) 10 A
    (C) 25 A
    (D) 40 A

16. The current rating of a protective device may:
    (A) be greater than the current-carrying capacity of the protected conductors supplying a motor
    (B) be greater than the current-carrying capacity of the protected conductors supplying a welder
    (C) not be greater than the current rating of protected equipment subject to short-time overload
    (D) not be greater than the current-carrying capacity of the protected conductors supplying any load.

17. The primary purpose of the additional requirements for electrical installations in hazardous areas is to:
    (A) seal the electrical system from the surrounding environment
    (B) reduce the energy in the electrical system
    (C) prevent the electrical system from igniting flammable materials
    (D) eliminate the corrosive effect of the environment on electrical equipment.

18. Ensuring that the electrical installation at a premises is safe for use by employees is the responsibility of the:
    (A) owner of the premisses
    (B) controller of the premises
    (C) site electrician
    (D) electrical contractor.

19. Type D circuit breakers are designed to trip:
    (A) in ranges of 12.5 to 15 times their rated current
    (B) in ranges of 5 to 10 times their rated current
    (C) 4 times their rated current
    (D) 7.5 times their rated current.

20. If an electrician is asked to work live he/she should first:
    (A) obtain appropriate personal protective equipment
    (B) obtain signed permission
    (C) question the need to work live
    (D) establish risk control measures.

Section B

1. An installation, which is earthed using the MEN system at the main switchboard, has an outbuilding supplied by a single phase sub main from main switchboard. What method/ methods may be used to earth the outbuilding?

2. What value of current is required to ensure effective operation of a circuit breaker under overload conditions?

3. What is the maximum allowable circuit fault loop impedance (Zs) for a 230 volt circuit supplying 10 amp socket outlets and protected by a 16 ampere fuse?

4. What action would need to be take if during visual inspection of an installation you found thermoplastic sheathed cables fixed to a wall within 2 m of the ground in a loading dock area?

5. A circuit has a maximum demand current of 18 amperes. If the cable selected has a current-carrying capacity of 21 amperes, could a 16 A, 20 A, 25 A or 32 A rated fuse protect the circuit? Explain your answer.

6. List the characteristic of supply that should be considered when designing/planning a multiple electrical installation.

7. Name **three** factors which will determine the number and type of circuits required in an electrical installation.

8. What requirements apply to luminaires near thermal insulation materials?

9. Describe how a residual current device works. You may use a diagram in your description.

10. Give examples where each of the **four** methods for determining the maximum demand in mains and submains are generally used.

11. How can you tell if an item of equipment meets the requirements for equipment selected for an electrical installation?

12. List the steps you would take to disconnect safely an electric motor for repair.

13. What value of operating current would cause a 20 A circuit breaker to operate in conventional time?

14. What can be determined from the sum of the current settings of the circuit breakers protecting final subcircuits on a sub board?

15. Under normal circumstances, what is the recommended minimum conductor size for a socket outlet?

Section C

1. Name the device represented in FigureT.1. Name each numbered component and briefly describe their purpose in the operation of the device.

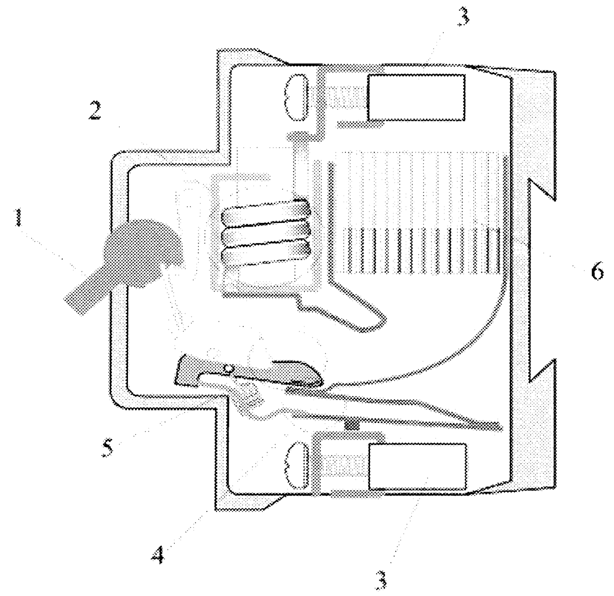


Figure T.1

2. Determine the suitability of a 16 A circuit breaker with a tripping characteristic in the range shown in Figure T.2. The circuit breaker is to protect a circuit supplying a motor that takes 5 seconds to start and has a maximum starting current of 80 A. Show all work and mark on the diagram how you arrived at your answer.

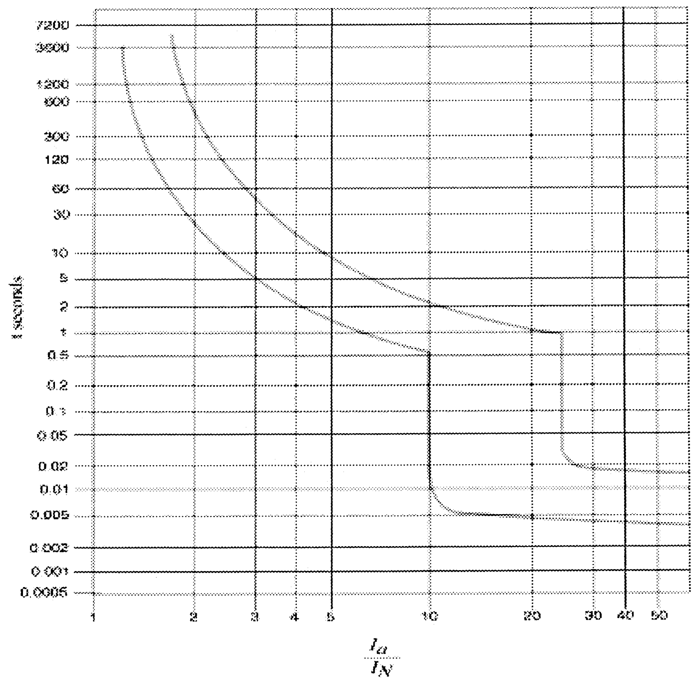


Figure T.2

3. In the electrical installation represented in Figure T.3 outbuilding 2 is to be supplied from outbuilding 1 and both outbuildings are to have a separate MEN installed. Show an acceptable arrangement of supply and earthing by drawing the supply and protective earthing conductors and writing on each conductor and termination the compliant Clause No.

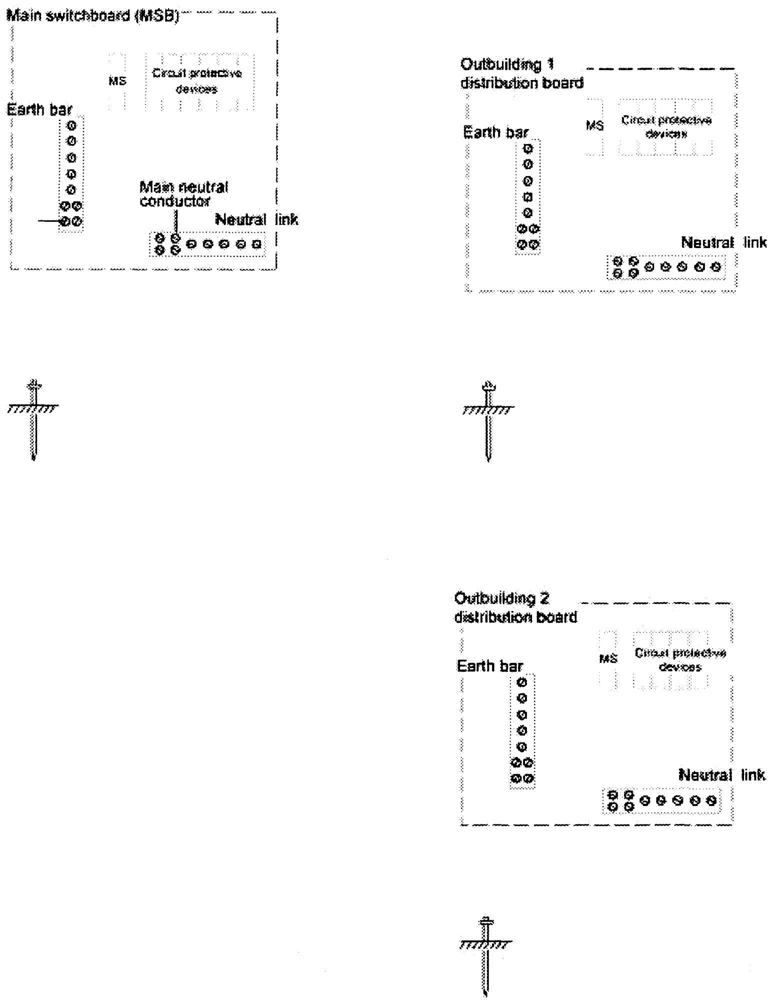


Figure T.3

4. In the main switchboard represented in Figure T.4 draw the supply and internal connections and identify the terminal to which the active and neutral conductor of each subcircuits is connected. One RCD is to protect the power circuits and one to protect the light circuits. All other circuits are to protected by individual MCBs.

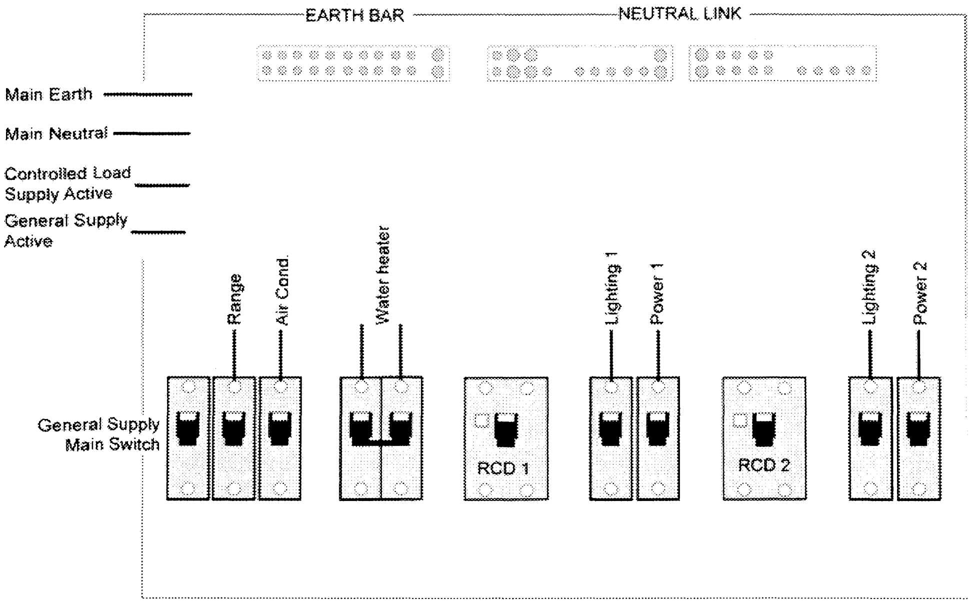


Figure T.4

Section D

1. A final sub-circuit supplies a load consisting of 230 V 10 A socket outlets and is protected by a 20 A type C circuit breaker. What is the maximum compliant internal fault-loop impedance of the final sub-circuit derived.

2. The maximum demand current of a sub-main in a non-domestic installation is calculated to be 120 ampere. The selected cable is 4-core, non-armoured, V90 insulated and sheathed, circular cable with copper conductors. Installation of the cable places it clipped directly to an internal wall with four other circuits in single layer touching, open to the air and protected by circuit breakers. What is the minimum conductor size for the cable?

3. A factory installation has a three-phase 230/400 V supply, and has a MEN earthing system. The maximum demand current of the installation is calculated at 180 amperes per phase. The greater portion of the maximum demand current is balanced over the three phases. The active conductors are 3 single-core, non-armoured; V90 insulated and sheathed circular cable with copper conductors. Installation of the cables places them in rigid thermoplastic conduit, buried in the ground at a depth of 500 mm where the ambient soil temperature is 25°C. The cables are protected by circuit breakers. Determine the minimum conductor size for the neutral conductor.

4. Calculate the maximum demand of a three-phase consumers mains to a block of 21 town houses units each having following load:
   - 18 only lighting points
   - 6 only single socket outlets
   - 12 only double socket outlets
   - 3.6 kW permanently connected air conditioner having full-load current of 18 A
   - 9.6 kW upright range
   - 4.8 kW off peak hot water service

5. Does the final subcircuit in the following non-domestic installation comply with the voltage drop limitations of the Wiring rules?

Consumer main:

- Supply: 3 phase 230/400 V
- Maximum demand: 65 A
- Route length: 30 m
- Cable size: 25 mm^2
- Cable configuration: V90 single core thermoplastic and sheathed copper conductors
- Cable installation: The circuit is enclosed in heavy-duty rigid thermoplastic conduit with no other circuits. Conduit is buried in the ground having an ambient soil temperature of 25°C and has a top cover of 0.65 m

Distribution Board 1 Sub-main:

- Supply 3 phase 230/400 V
- Maximum demand: 45 A
- Route length: 40 m
- Cable size: 16 mm^2
- Cable configuration: V90 single core thermoplastic and sheathed copper conductors
- Cable installation: The cables are clipped to the building structure in trefoil formation and installed in single circuit configuration, unen-closed in air

Final sub-circuit supplied from Distribution Board 1:

- Supply 1 phase 230 V
- Maximum demand: 28 A
- Route length: 30 m
- Cable size: 6 mm^2
- Cable configuration: V90 two-core and earth thermoplastic and sheathed copper conductors
- Cable installation: The cables are clipped to the building structure and installed in single circuit configuration, unenclosed in air

6. Determine the minimum rating of a main switchboard supplied with 3 phase from a 1000 kVA 11 kV/400 V transformer. The external line-to-line impedance is 0.0645 Ω.

Test 2 - Installation planning

Student equipment required

- AS/NZS 3000:2000 Wiring rules with amendments and marginal notes
- AS/NZS 3008.1.1:1998 Electrical installation - Selection of cables
- AS/NZS 3017:2001 Electrical installations - Testing and inspection guidelines
- Non-programmable calculators.

Electrical Installation Planning

What you are required to do in this test

You are to:

A. Select a cable for a submain in a non-domestic installation

B. Select a protection device for the submain.

The criteria on which you will be assessed are:

- Determining the minimum current-carrying capacity for the submain
- Selecting a cable size with regards to:
  - sufficient current-carrying capacity,
  - 3 phase voltage drop not exceeding 3 V, and
  - a sufficiently low fault-loop impedance.
- Selecting an appropriately rated protective device.

Details of the installation

A commercial/industrial complex consists of six separate occupancies. The distribution board for each occupancy is supplied from a main switchboard for the complex. You are to select the cable and protective device for the submain to Unit 6. Details of the installation are given in Figures T5 and T6 below.

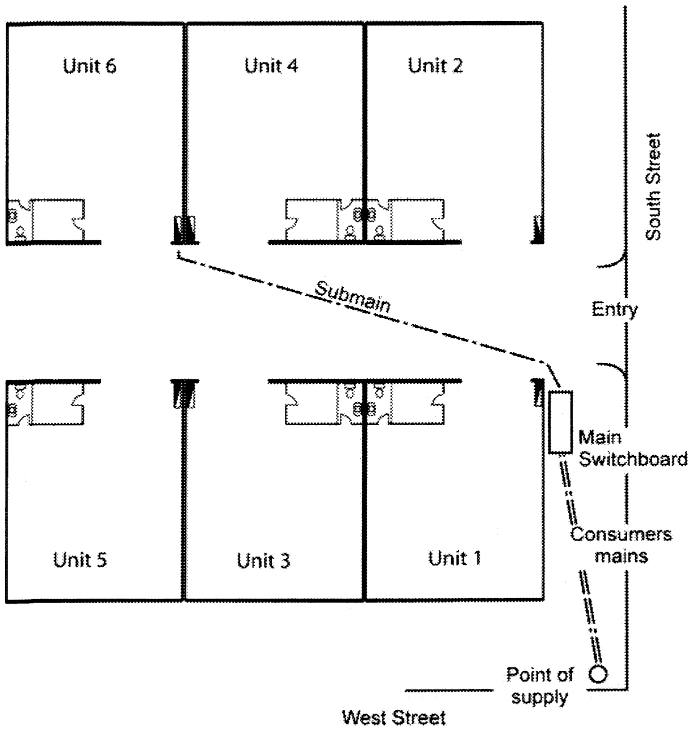
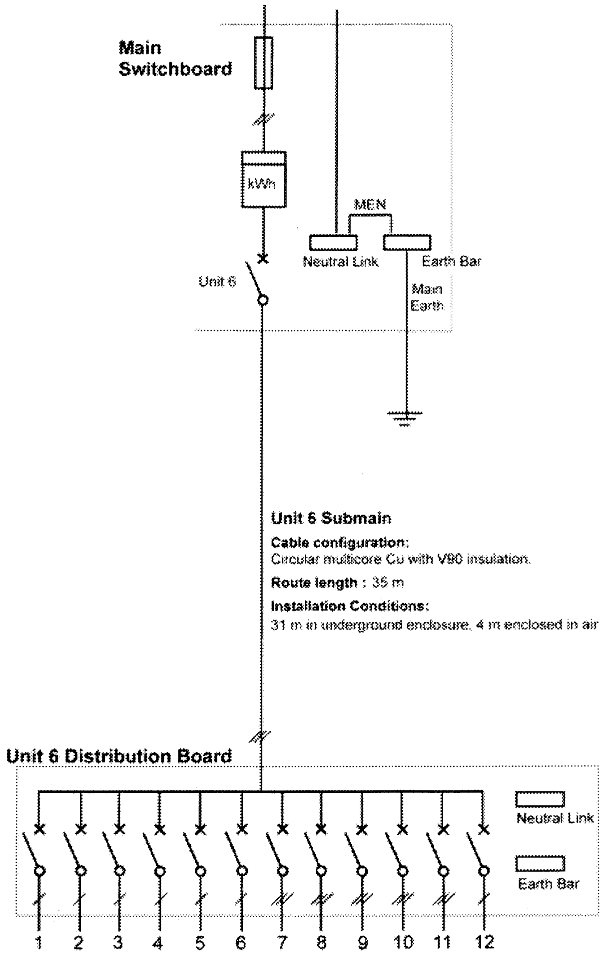


Figure T5 Site plan

Installation Planning



Circuit	Load Group	Rating	Quantity
1	Lighting	0.78 A	11
2	Lighting	0.78 A	9
3	Lighting	0.78 A	9
4	1 Ø Socket outlets	10 A	4
5	1 Ø Socket outlets	10 A	8
6	1 Ø Socket outlets	10 A	8
7	3 Ø Socket outlets	10 A	1
8	3 Ø Socket outlets	10 A	1
9	3 Ø Socket outlets	10 A	1
10	3 Ø Socket outlets	10 A	1
11	3 Ø Socket outlets	32 A	1
12	Water heater	15A	1

Figure T6 Circuit arrangements and loads

Sample Assessment - Electrical Installation Planning

1. Determine the maximum demand for the submain

Allow an additional 10% for future increase in load.

Equipment	*Load group*	*Calculation*	*Red A*	*White A*	*Blue A*
		Additional 10% for future			
		Maximum demand			

2. Cable selection based on current-carrying capacity

Full description of the cable selected: ______________________________

Standard used: ______________________________

Table No: ______________________________

Column No: ______________________________

Rating/Derating factor: ______________________________

3. Cable selection based on voltage-drop limitations

Does the 3 phase voltage drop in the cable size selected exceed 3 V as specified?

Show all calculation workings

The 3 phase voltage-drop of the cable is ____________________

Does the cable meet voltage drop limitations? ________________

4. Protective device selection

Description of the selected device: ____

Rating: ____

Type: ____

Maximum value of internal fault-loop impedance _____________ Standard Table No.____________

5. Determine the size of the main earth conductor to unit 6

Earth conductor size: ____

Standard used: ____

Table No: ____

6. For the protective device you have selected, determine if the circuit complies with fault loop impedance limitations

Test 3 - Practical test

Student equipment required

- AS/NZS 3000:2000 Wiring rules with amendments and marginal notes
- AS/NZS 3008.1.1:1998 Electrical installation - Selection of cables
- AS/NZS 3017:2001 Electrical installations - Testing and inspection guidelines
- Non-programmable calculators

Electrical Installation Practical

What you are required to do in this test

You are to carry out the following tasks:

A. Demonstrate correct isolation, disconnection and reconnection procedures.

B. Install an MEN earthing system.

C. Test an installation to verify whether the requirements on the Wiring rules are met.

Task A Demonstrate correct isolation, disconnection and reconnection procedures

The criteria on which you will be assessed for this task are:

- working safely
- correctly isolating a piece of electrical equipment operating at low voltage
- correctly applying circuit lockout procedures
- correctly disconnect electrical equipment
- correctly reconnect electrical equipment.

Instructions

1. Isolate the electrical equipment AS DIRECTED BY YOUR ASSESSOR. Write information about your procedure in the space provided; include the type of test equipment used.

   Safety procedures followed:

   ____

   ____

   ____

   ____

   ____

2. Disconnect the electrical equipment AS DIRECTED BY YOUR ASSESSOR. Write information about your procedure in the space provided; include the type of test equipment used.

   Safety procedures followed:

   ____

   ____

   ____

   ____

   ____

3. Reconnect the electrical equipment AS DIRECTED BY YOUR ASSESSOR. Write information about your procedure in the space provided; include the type of test equipment used.

   Safety procedures followed:

   ____

   ____

   ____

   ____

   ____

Task B Install an MEN earthing system

The criteria on which you will be assessed for this task are:

- working safely
- selecting the correct size condutors
- installing and connecting the wiring to conform with the Wiring rules requirements for a MEN earthing system.

Installation specifications:

- consumers mains - as indicated by your assessor
- active conductor - as indicated by your assessor
- neutral condutor - as indiated by your assessor.

Instructions

Install a MEN earthing system AS DIRECTED BY YOUR ASSESSOR. Write information about your installation in the spaces provided.

Safety procedures followed:

____

____

____

____

____

Description of conductors used

Main earthing conductor ______________________

Equipotential bonding conductor ______________________

Main neutral condutor ______________________

MEN link ______________________

Task C Test an installation to verify whether the requirements of the Wiring Rules are met.

The criteria on which you will be assessed are:

- preparing for each test safely
- selecting and adjusting the correct testing device for each test
- determining whether a test result shows that part of the installation meets the requirements of the Wiring rules
- identifying faults in the installation from test results, and
- identifying the possible causes of any fault.

Instructions

Perform the tests listed below AS INSTRUCTED BY YOUR ASSESSOR. Write the information about each test you carry out in the spaces provided. Some parts of the installation will have non-compliance faults

TESTING IS TO BE PERFORMED **WITHOUT** SUPPLY CONNECTED.

1. Insulation resistance of the whole installation

Test preparation followed:

____

____

____

____

Testing device

Used: ______________________________

Preparation: ______________________________

Test results

☐ Compliance ☐ Non-compliance

Reading ________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

____

2. Earth continuity and resistance of the main earthing conductor

Test preparation followed:

____

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

☐ Compliance ☐ Non-compliance

Reading __________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

3. Earth continuity and resistance of the protective earthing conductor

Test preparation followed:

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

☐ Compliance ☐ Non-compliance

Reading __________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

4. Polarity test of submains

Test preparation followed:

____

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

☐ Compliance ☐ Non-compliance

Reading ____________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

5. Polarity test of power circuits

Test preparation followed:

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

☐ Compliance ☐ Non-compliance

Reading ____________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

6. Polarity test of lighting circuits

Test preparation followed:

____

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

☐ Compliance ☐ Non-compliance

Reading ____________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

7. Polarity test of range circuit

Test preparation followed:

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

☐ Compliance ☐ Non-compliance

Reading ____________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

8. Polarity test of water heater circuit

Test preparation followed:

____

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

Reading ____________________ Results show ☐ Compliance ☐ Non-compliance

If the result shows non-compliance what are the possible causes?

____

____

9. Interconnection test between conductors of different circuits

Test preparation followed:

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

Reading ____________________ Results show ☐ Compliance ☐ Non-compliance

If the result shows non-compliance what are the possible causes?

____

____

10. Internal fault-loop impedance test of each circuit

Test preparation followed:

____

____

____

____

Testing device

Used: ____

Preparation: ____

Test results

☐ Compliance ☐ Non-compliance

Reading ____________________ Results show

If the result shows non-compliance what are the possible causes?

____

____

____

Follow the instructions of your assessor when you have completed all testing required.

Notes

Sample Assessment - Electrical Knowledge Test - Answers

Section A

1. (A) Category A underground wiring system.

2. (B) Prospective fault current.

3. (C) Requirements of the Wiring Rules and local Service Rules.

4. (C) The voltage between simultaneously accessible parts.

5. (D) Owner/controller of a work site and employers and their employees.

6. (A) Be supplied from a circuit protected by an RCD.

7. (B) Completion of work must be signed-off by the person who did the work.

8. (D) Low enough for correct operation of the protective device.

9. (C) 0.4s for circuit supplying portable equipment and 5s for circuits supplying fixed appliances.

10. (C) Be safe to use and not cause danger.

11. (C) A HRC fuse.

12. (C) Flammable contaminates and oxygen depletion.

13. (C) Fixing and location of the equipment and rating of overload protective devices.

14. (B) 52 m.

15. (C) 25 A.

16. (D) Not be greater than the current-carrying capacity of the protected conductors supplying any load.

17. (C) Prevent the electrical system from igniting flammable materials.

18. (C) Site electrician.

19. (A) Iin ranges of 12.5 to 15 times their rated current.

20. (C) Question the need to work live.

Section B

1. Clause 5.6.6

2. Clause 2.4.3.2 - 1.45 I_z

3. Clause B4.5 - 3.07 Ω

4. Clause 3.3.7 - mechanical protection.

5. Clause 2.4.2 - No, cable must be derated by 0.9.

6 Clause 1.8.2

7. Clause 1.8.5

8. Clause 4.3.6.3

9. Design to trip when the difference between the active and neutral current differs by more than 30 mA. This difference is current flowing in the earthing conductor.

10.

Calculated	- Clause 1.8.3.2. - Appendix C - Domestic installations
Assessed	- Clause 1.8.3.3. - Large or complex installations
Measured	- Clause 1.8.3.4. - Maximum demand indicator on existing installations
Limited	- Clause 1.8.3.5. - Fixed circuit breaker on lightly loaded equipment

11. Clause 1.9

12. Locate circuit breaker or fuse.
Check voltage tester is working on known live supply.
Switch off circuit break or remove fuse.
Test motor terminals to ensure supply is off.
Attach 'out-of-service' tag to circuit breaker or fuse.
Remove fuse elements and replace wedges if appropriate.

13. 29 A

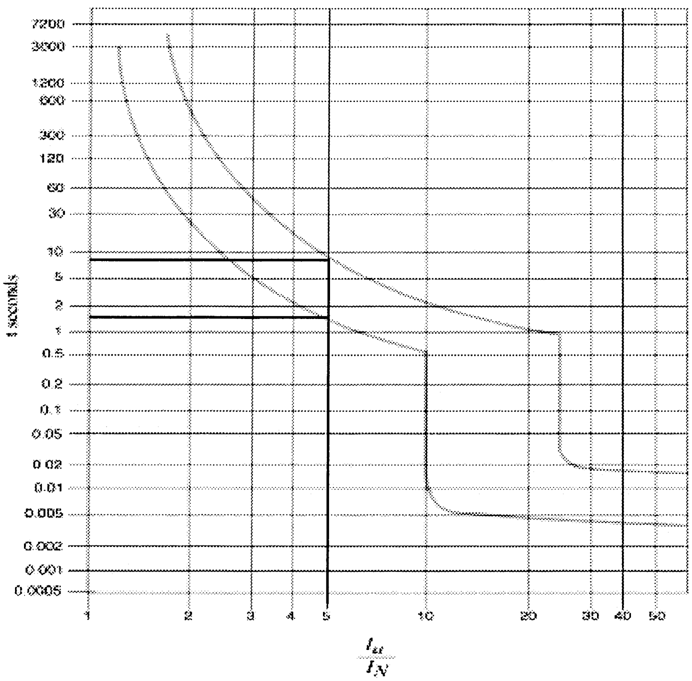
14. Clause 1.8.3.5. - The submain maximum demand.

15. Table 3.4 - 2.5 mm^2

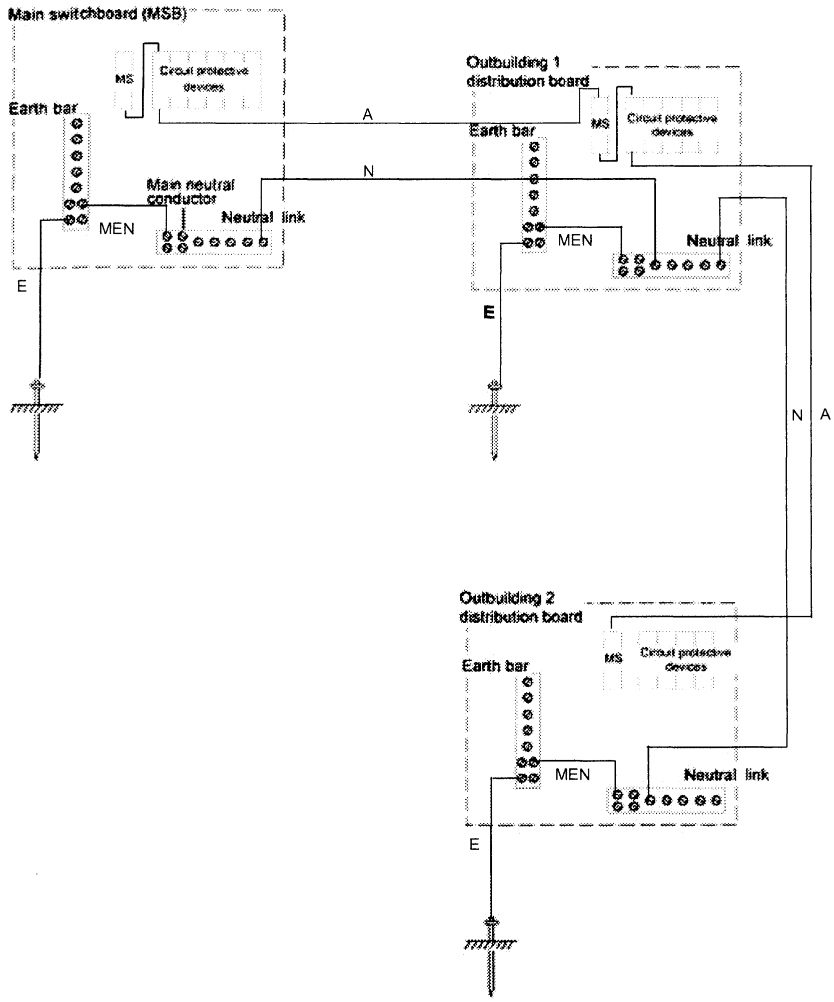
Section C

1. Thermal - magnetic circuit breaker.
   1. toggle
   2. magnetic trip
   3. wiring terminals
   4. contacts
   5. thermal trip
   6. de-ion grid.

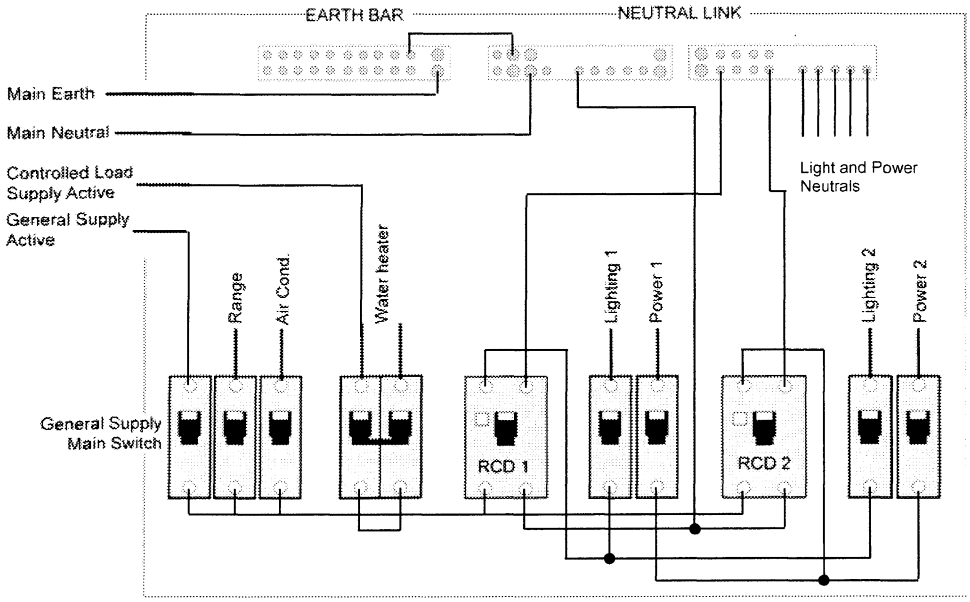
2. Circuit breaker trip between 1.5 to 9 sec, therefore it is not suitable.



3.


Main switchboard (MSB)
MS
Circuit protective devices
Earth bar
Main neutral conductor
Neutral link
MEN
E
A
N
Outbuilding 1 distribution board
MS
Circuit protective devices
Earth bar
MEN
Neutral link
E
N
A
Outbuilding 2 distribution board
MS
Circuit protective devices
Earth bar
MEN
Neutral link
E

4.



Section D

1. 2.45 Ω

2. 70 mm^2

3. 10 mm^2

4. 204.1 A

5. Yes, V_D = 11.07 V

6. 6.2 kA

Sample Assessments - Electrical Installation Planning - Answers

Test 2

1. 89.2 A

2. 25 mm^2

3. 5.03 V - Too high

   50 mm^2 cable must be used.

4. 100 A type C circuit breaker

   $Z_{FL} = 0.31\ \Omega$

5. 16 mm^2

6. Circuit length can be 132.2 m.

Appendix A - Sample Single Domestic Installation

This appendix provides details of a sample single domestic installation. It includes:

- floor plan
- site plan
- electrical schedule

Construction details:

The cottage is of brick-veneer construction having cement roof tiles, timber frame, and built on a reinforced concrete slab on the ground. Internal walls are lined with plasterboard and bulk thermal insulation is fitted to the ceiling void.

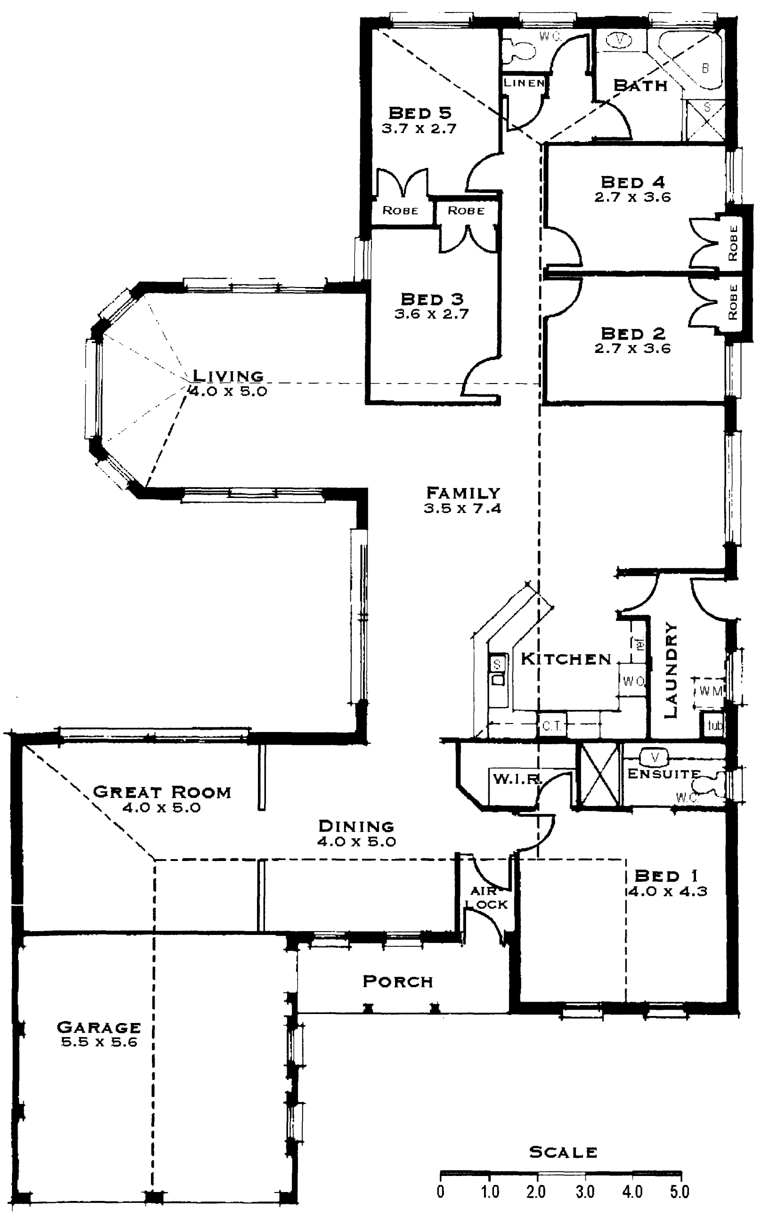


Figure A1 Sample floor plan for house

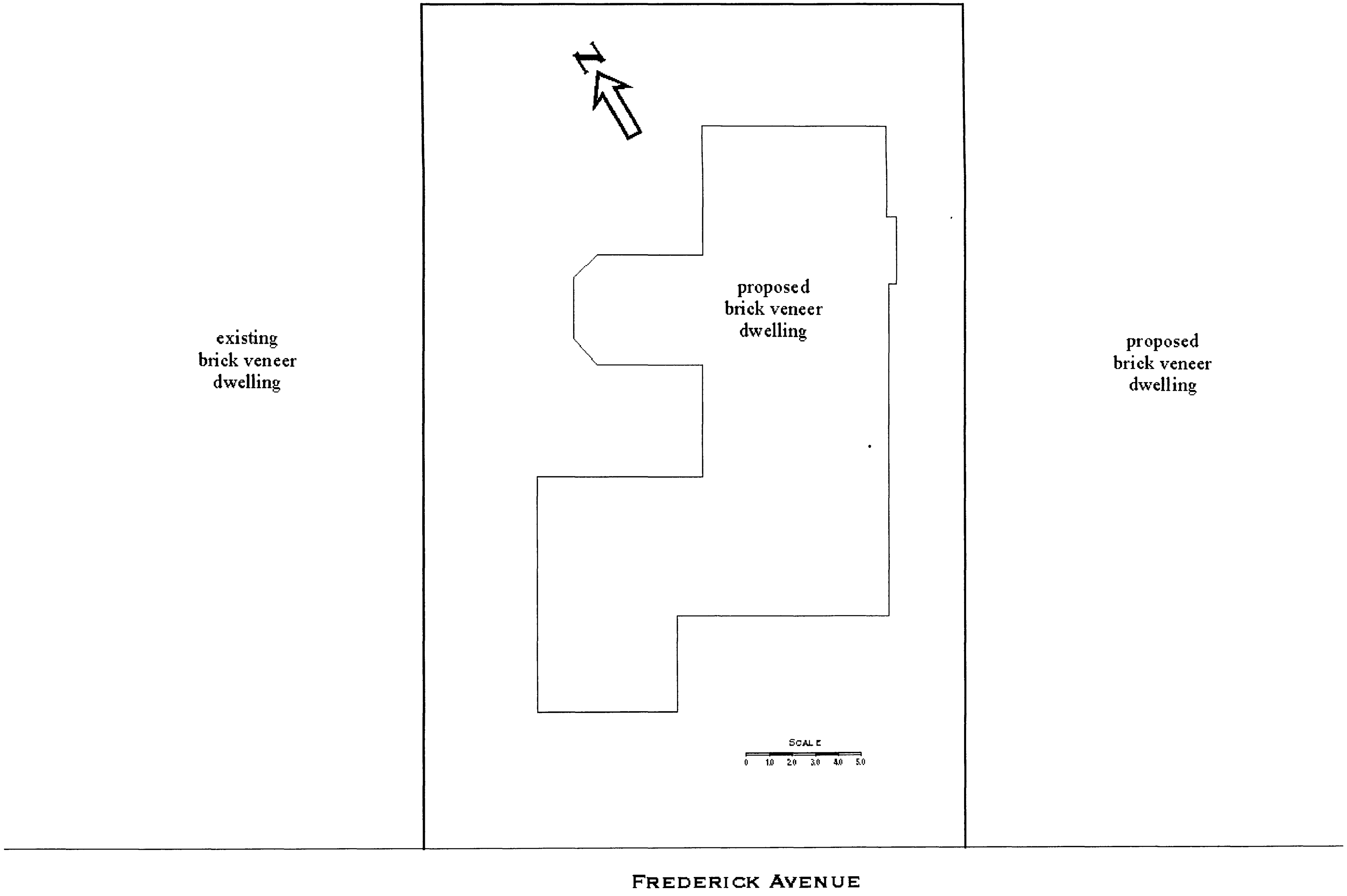


Figure A2 Sample site plan for house

Table A1 Lighting schedule

Room	Location	Plan No	Appliance	Make / No.	Watt	Mounting	Supply	Install
Porch	Bed 1 wall	1	Cast coach light	Morewatt / CL2	60	Ext wall	P	C
	Dining wall	2	Cast coach light	Morewatt / CL2	60	Ext wall	P	C
Airlock	Central	3	250mm round diffused	HiLume / R250	100	Ceiling	P	C
Garage	Spread }	4	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
	Centrally }	5	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
	Over each }	6	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
	bay }	7	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
Great	Spread }	8	350mm round diffused	HiLume /R350	60	Ceiling	P	C
	Centrally }	9	350mm round diffused	HiLume / R350	60	Ceiling	P	C
Dining	Spread }	10	350mm round diffused	HiLume /R 350	60	Ceiling	P	C
	Centrally }	11	350mm round diffused	HiLume / R350	60	Ceiling	P	C
Bed 1	Central	12	250mm round diffused	HiLume /R250	60	Ceiling	P	C
Ensuite	Central	13	Comb light/fan	Megawatt / MW2	100	Ceiling	P	C
WIR	Central	14	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Laundry	Central	15	250mm round diffused	HiLume /R 250	60	Ceiling	P	C
Kitchen	Spread }	16	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	17	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Over bench }	18	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	tops }	19	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	adj Family	20	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	adj Family	21	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
Family	Spread }	22	5 light pendant	Canela / PL5	300	Ceiling	P	C
	Centrally }	23	5 light pendant	Canela / PL5	300	Ceiling	P	C
Living	Spread }	24	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	25	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Spread }	26	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	27	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Spread }	28	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	29	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
Bed 2	Central	30	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 3	Central	31	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 4	Central	32	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 5	Central	33	250mm round diffused	HiLume / R 250	60	Ceiling	P	C
Bath	Central	34	Comb light/fan	Megawatt / MW3	100	Ceiling	P	C
Hall	o/s linen	35	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	o/s Bed 3	36	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
External	o/s laundry	37	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C
	o/s family	38	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C
	o/s great	39	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C

P = Proprietor C = Contractor

Table A2 Power schedule

Room	Location	Plan No	Appliance	Make / No.	Watt	Mounting	Supply	Install
Porch	Bed 1 wall	1	Cast coach light	Morewatt / CL2	60	Ext wall	P	C
	Dining wall	2	Cast coach light	Morewatt / CL2	60	Ext wall	P	C
Airlock	Central	3	250mm round diffused	HiLume / R250	100	Ceiling	P	C
Garage	Spread }	4	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
	Centrally }	5	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
	Over each }	6	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
	bay }	7	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	P	C
Great	Spread }	8	350mm round diffused	HiLume /R350	60	Ceiling	P	C
	Centrally }	9	350mm round diffused	HiLume / R350	60	Ceiling	P	C
Dining	Spread }	10	350mm round diffused	HiLume /R 350	60	Ceiling	P	C
	Centrally }	11	350mm round diffused	HiLume / R350	60	Ceiling	P	C
Bed 1	Central	12	250mm round diffused	HiLume /R250	60	Ceiling	P	C
Ensuite	Central	13	Comb light/fan	Megawatt / MW2	100	Ceiling	P	C
WIR	Central	14	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Laundry	Central	15	250mm round diffused	HiLume /R 250	60	Ceiling	P	C
Kitchen	Spread }	16	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	17	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Over bench }	18	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	tops }	19	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	adj Family	20	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	adj Family	21	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
Family	Spread }	22	5 light pendant	Canela / PL5	300	Ceiling	P	C
	Centrally }	23	5 light pendant	Canela / PL5	300	Ceiling	P	C
Living	Spread }	24	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	25	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Spread }	26	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	27	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Spread }	28	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	29	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
Bed 2	Central	30	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 3	Central	31	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 4	Central	32	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 5	Central	33	250mm round diffused	HiLume / R 250	60	Ceiling	P	C
Bath	Central	34	Comb light/fan	Megawatt / MW3	100	Ceiling	P	C
Hall	o/s linen	35	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	o/s Bed 3	36	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
External	o/s laundry	37	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C
	o/s family	38	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C
	o/s great	39	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C

P = Proprietor C = Contractor

Table A3 Fixed appliance schedule

Room	Location	Plan No	Appliance	Make / No.	A	Mounting	Supply	Install
External	o/s Bed 3	1	Single Phase Split A/C	Freezeme RC101	18	On ground	P	C
	o/s Laundry	2	2 element 350L OPHWS	Thermozon 350	20/20	On ground	P	C
Kitchen	Cook-top	3	IR Cook-top	Quazer V395	9kW	Bench top	P	C
	wall Oven	4	Convection oven	Quazer O350	4kW	Cupboard	P	C

P = Proprietor C = Contractor

Appendix B - Sample Multiple Domestic Installation

This appendix provides details of a sample multiple domestic installation. It includes:

- floor plan
- site plan
- electrical schedule

Construction details:

The units are of brick-veneer construction having cement roof tiles, timber frame, and built on a reinforced concrete slab on the ground. Internal walls are lined with plasterboard and bulk thermal insulation is fitted to the ceiling void. The common wall is of double brick construction from floor to the underside of the roof tiles.

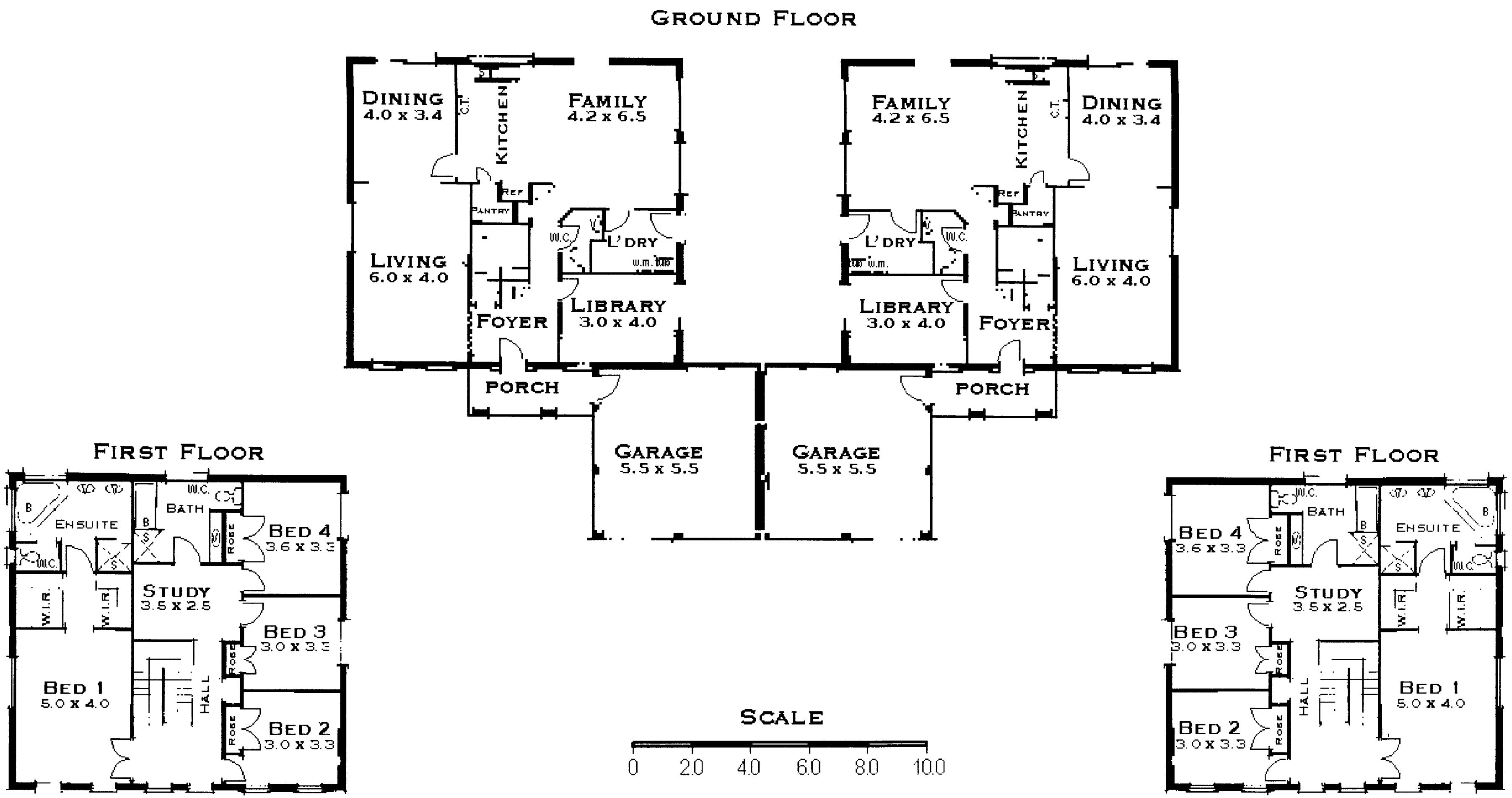


Figure B1 Sample multiple domestic floor plan

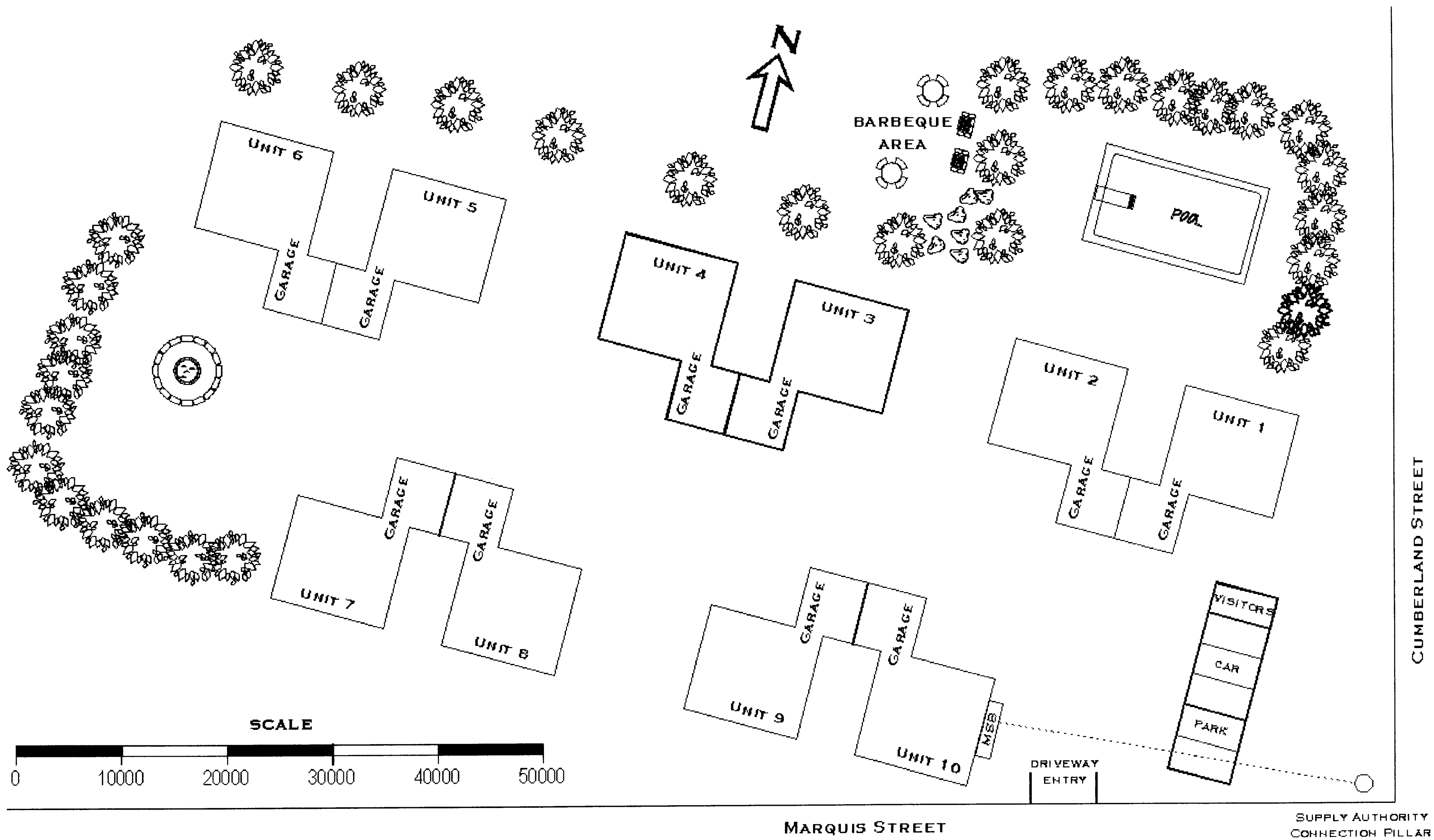


Figure B2 Sample multiple domestic site plan

Table B1 Lighting schedule

Room	Location	Plan No	Appliance	Make / No.	Watt	Mounting	Supply	Install
Porch	Central	1	250mm round diffused	HiLume / R250	100	Ceiling	P	C
Foyer	Central	2	250mm round diffused	HiLume / R250	100	Ceiling	P	C
Stair	Central	3	250mm round diffused	HiLume / R250	100	Ceiling	P	C
Garage	Spread }	4	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	C	C
	Centrally }	5	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	C	C
	Over each }	6	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	C	C
	bay }	7	2/36W diff Troffer	HiLume / TR3	2/36	Ceiling	C	C
Library	Spread }	8	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	9	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Over bench }	10	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	tops }	11	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	adj Family	12	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	adj Family	13	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
Dining	Spread }	14	3 light pendant	Canela / PL3	180	Ceiling	P	C
	Centrally }	15	3 light pendant	Canela / PL3	180	Ceiling	P	C
Laundry	Central	16	250mm round diffused	HiLume /R 250	60	Ceiling	P	C
Kitchen	Spread }	17	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	18	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Over bench }	19	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Tops }	20	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	}	21	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	}	22	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
Family	Spread }	23	5 light pendant	Canela / PL5	300	Ceiling	P	C
	Centrally }	24	5 light pendant	Canela / PL5	300	Ceiling	P	C
Living	Spread }	25	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	26	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Spread }	27	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	28	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Spread }	29	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	30	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
L'er Hall	Central	31	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 1	Central	32	250mm round diffused	HiLume /R250	60	Ceiling	P	c
Ensuite	Central	33	Comb light/fan	Megawatt / MW2	100	Ceiling	P	C
WIR	Central	34	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 2	Central	35	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 3	Central	36	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bed 4	Central	37	250mm round diffused	HiLume / R250	60	Ceiling	P	C
Bath	Central	38	Comb light/fan	Megawatt / MW3	100	Ceiling	P	C
Study	Spread }	39	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	Centrally }	40	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	}	41	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
	}	42	100mm ELV downlight	Morewatt / DL3	50	Ceiling	P	C
Upper Hall	o/s study	43	250mm round diffused	HiLume / R250	60	Ceiling	P	C
	o/s Bed 1	44	250mm round diffused	HiLume / R250	60	Ceiling	P	C
	o/s Bed 2	44	250mm round diffused	HiLume / R250	60	Ceiling	P	C
External	o/s garage	45	Cast coach light	Morewatt / CL2	60	Ext wall	P	P
	o/s garage	46	Cast coach light	Morewatt / CL2	60	Ext wall	P	C
	o/s laundry	47	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C
	o/s family	48	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C
	o/s living	49	1/36 batten fluorescent	Candelux / BB36	1/36	Eaves	C	C

P = Proprietor C = Contractor

Table B2 Power schedule

Room	Location	Plan No	Appliance	Make / No.	A	Mounting	Supply	Install
Garage	Rear wall	1	Double socket outlet	Morewatt / B5	10	1800mm	C	C
	Rear wall	2	Double socket outlet	Morewatt / B5	10	1800mm	C	C
Foyer	Adj library	3	Single socket outlet	Morewatt / B3	10	400mm	C	C
Library	Adj foyer	4	Double socket outlet	Morewatt / B5	10	400mm	C	C
	Adj laundry	5	Double socket outlet	Morewatt / B5	10	400mm	C	C
Dining	o/s wall	6	Double socket outlet	Morewatt / B5	10	400mm	C	C
	o/s wall	7	Double socket outlet	Morewatt / B5	10	400mm	C	C
	adj kitchen	8	Double socket outlet	Morewatt / B5	10	400mm	C	C
Laundry	Wash Mch	9	Double socket outlet	Morewatt / B5	10	1200mm	C	C
Kitchen	Range hood	10	Single socket outlet	Morewatt / B3	10	2200mm	C	C
	Fridge	11	Single socket outlet	Morewatt / B3	10	1800mm	C	C
	Work area	12	Double socket outlet	Morewatt / B5	10	900mm	C	C
	Work area	13	Double socket outlet	Morewatt / B5	10	900mm	C	C
	Adj sink	14	Double socket outlet	Morewatt / B5	10	900mm	C	C
	Below sink	15	Single socket outlet	Morewatt / B3	10	600mm	C	C
Family	Laundry wall	16	Double socket outlet	Morewatt / B5	10	400mm	C	C
	o/s wall	17	Double socket outlet	Morewatt / B5	10	400mm	C	C
Living	Pantry wall	18	Double socket outlet	Morewatt / B5	10	400mm	C	C
	Foyer wall	19	Double socket outlet	Morewatt / B5	10	400mm	C	C
	o/s wall	20	Double socket outlet	Morewatt / B5	10	400mm	C	C
	o/s wall	21	Double socket outlet	Morewatt / B5	10	400mm	C	C
Bed 1	Stair wall	22	Double socket outlet	Morewatt / B5	10	400mm	C	C
	o/s wall	23	Double socket outlet	Morewatt / B5	10	400mm	C	C
	WIR wall	24	Double socket outlet	Morewatt / B5	10	400mm	C	C
	WIR wall	25	Double socket outlet	Morewatt / B5	10	400mm	C	C
Ensuite	Adj vanity	26	Single socket outlet	Morewatt / B3	10	1350mm	C	C
Bed 2	o/s wall	27	Double socket outlet	Morewatt / B5	10	400mm	C	C
	Bed 3 wall	28	Double socket outlet	Morewatt / B5	10	400mm	C	C
Bed 3	Bed 2 wall	29	Double socket outlet	Morewatt / B5	10	400mm	C	C
	Bed 4 wall	30	Double socket outlet	Morewatt / B5	10	400mm	C	C
Bed 4	Bed 3 wall	31	Double socket outlet	Morewatt / B5	10	400mm	C	C
	o/s wall	32	Double socket outlet	Morewatt / B5	10	400mm	C	C
Study	Stair wall	33	Double socket outlet	Morewatt / B5	10	400mm	C	C
	WIR wall	34	Double socket outlet	Morewatt / B5	10	400mm	C	C
Bath	Adj Vanity	35	Single Socket Outlet	Morewatt / B3	10	1350mm	C	C
Stair	Landing	36	Single Socket Outlet	Morewatt / B3	10	400mm	C	C

P = Proprietor C = Contractor

Table B3 Fixed appliance schedule

Room	Location	Plan No	Appliance	Make / No.	A	Mounting	Supply	Install
External	o/s Family	1	Single Phase Split A/C	Freezeme RC101	18	On ground	P	C
	o/s Laundry	2	2 element 350L OPHWS	Thermozon 350	20/20	On ground	P	C
Kitchen	Cook-top	3	IR Cook-top	Quazer V395	9kW	Bench top	P	C
	wall Oven	4	Convection oven	Quazer O350	4kW	Cupboard	P	C

P = Proprietor C = Contractor

Table B4 Communal schedule

Location	Plan No	Appliance	Make / No.	A	Mounting	Supply	Install
Outside Unit 1 Garage	1	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 2 Garage	2	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 3 Garage	3	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 4 Garage	4	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 5 Garage	5	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 6 Garage	6	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 7 Garage	7	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 8 Garage	8	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 9 Garage	9	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Outside Unit 10 Garage	10	18W Bollard	Luma BOL-18	0.12	Pole	C	C
RH side driveway entry	11	18W Bollard	Luma BOL-18	0.12	Pole	C	C
LH side driveway entry	12	18W Bollard	Luma BOL-18	0.12	Pole	C	C
Barbecue area	13	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
	14	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
	15	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
	16	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
Swimming pool area	17	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
	18	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
	19	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
	20	500W halogen flood	Brilite FL-500	2.5	Pole	C	C
	21	pump motor	Ungi 500	3.4	covered	P	C

P = Proprietor C = Contractor

Appendix C - Sample Non-Domestic Installation

This appendix provides details of a sample non-domestic installation. It includes:

- ❑ floor plan
- ❑ site plan
- ❑ electrical schedule

Construction details:

The factory units have pre-cast concrete walls attached to a steel frame support on a concrete slab. The metal roof sheeting attaches directly to the roof support members and has thermal insulation on the underside.

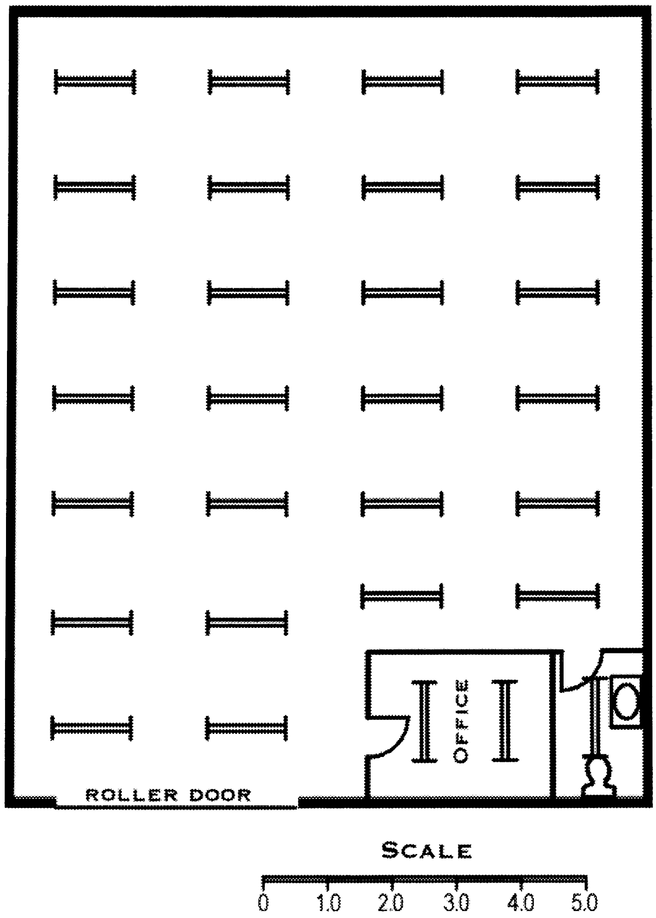


Figure C1 Sample non-domestic installation floor plan

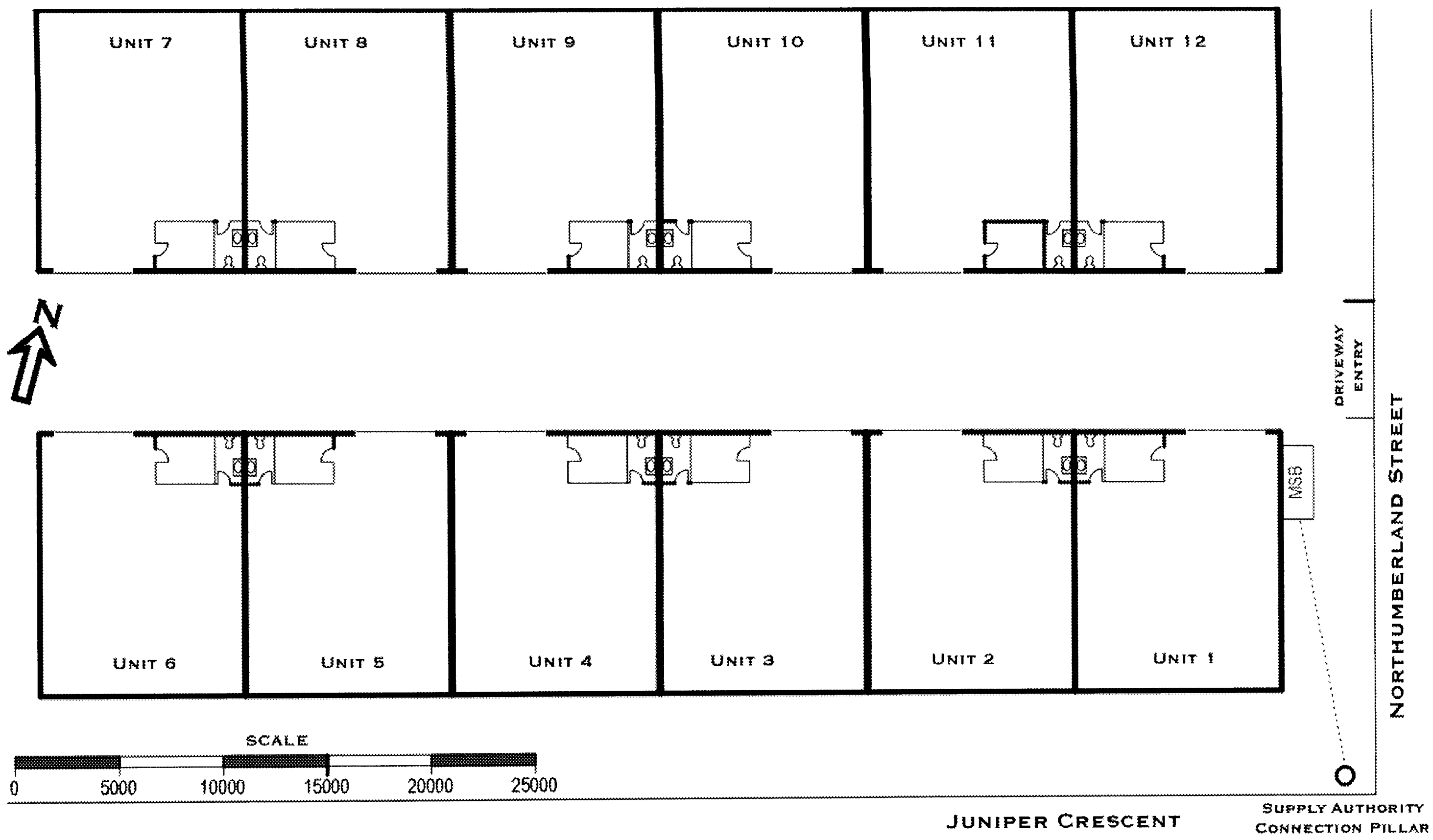


Figure C2 Sample non-domestic installation site plan

Table C1 Electrical schedule

Circuit	Phases	Location	Appliance	Qty	Make / No.	A (ea)	Mounting	Supply	Install
1	Single	Factory	2/36W diff Troffer	8	HiLume / TR3	0.78	Suspended	C	C
2	Single	Factory	2/36W diff Troffer	9	HiLume / TR3	0.78	Suspended	C	C
3	Single	Factory	2/36W diff Troffer	9	HiLume / TR3	0.78	Suspended	C	C
4	Single	Office toilet	2/36W diff Troffer 2/36W diff Troffer	2 1	HiLume / TR3 HiLume / TR3	0.78 0.78	Ceiling Ceiling	C C	C C
5	Single	Office toilet	Single socket outlet Single socket outlet	3 1	Morewatt / B3 Morewatt / B3	10 10	Wall Wall	C C	C C
6	Single	Factory	Single socket outlet	8	Morewatt / B3	10	Wall	C	C
7	Single	Factory	Single socket outlet	8	Morewatt / B3	10	Wall	C	C
8	Three	Factory	3-phase socket outlet	1	MoPower / 32	32	Wall	C	C
9	Three	Factory	3-phase socket outlet	1	MoPower / 32	32	Wall	C	C
10	Three	Factory	3-phase socket outlet	1	MoPower / 32	32	Wall	C	C
11	Three	Factory	3-phase socket outlet	1	MoPower / 50	50	Wall	C	C
12	Three	Factory	3-phase socket outlet	1	MoPower / 50	50	Wall	C	C
13	Single	Factory	Quick recovery water heater	1	Vulca /110	15	Floor	P	C

P = Proprietor C = Contractor