Government of Western Australia
North Metropolitan TAFE

UEE 11 Training Package Support Material

(Non-Endorsed Component)

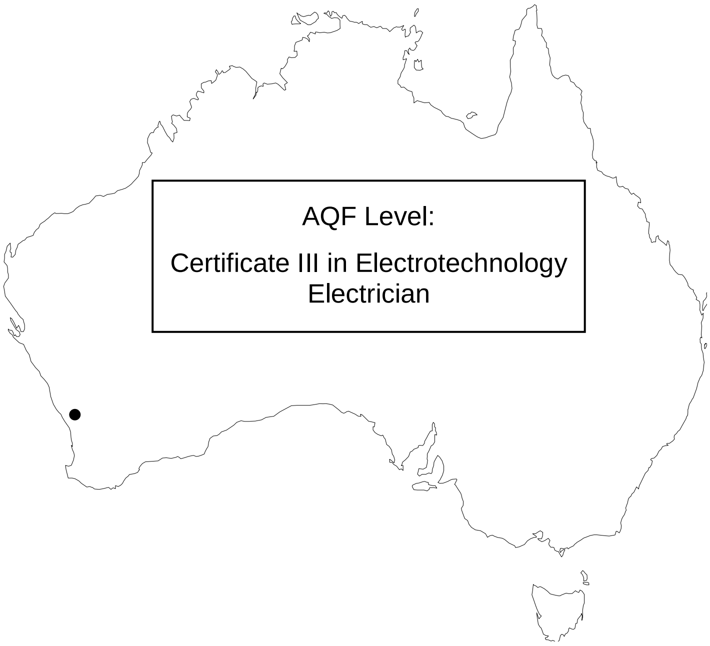
Based on:

National Electrotechnology Industry Standards

Resource Book

UEENEEG107A

Select Wiring Systems and Cables for Low Voltage General Electrical Installations



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NMTAFE

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Version 2 – 08/2018 – Alignment with AS/NZS3000:2018

Acknowledgements

This Unit Guide has been prepared by Balga Campus Lecturers.

It is intended for North Metropolitan TAFE students only.

Manager Publications and Distributions

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UEENEEG107A Select wiring systems and cables for low voltage general electrical installations

C O N T E N T S

Work Completed:

Section	**Topic**	Completed
1	Performance of an Electrical Installation – Worksheet 1	
2	Methods of Ensuring Safety and Protection Against Damage – Worksheet 2	
3	Circuit Arrangements – Worksheet 3	
4	Wiring Systems – Worksheet 4	
5	Selection of Cables for an Installation – Worksheet 5.1	
	Maximum Demand of Consumer's Mains and Submains - Worksheet 5.2	
	Voltage Drop in Cables – Worksheet 5.3	
	Cable selection based on fault loop impedance requirements – Worksheet 5.4	
	Cable Selection for Final Subcircuits – Worksheet 5.5	
	Motor Installation Work Sheet – Worksheet 5.6	
	Maximum Demand in Multiple Installations – Worksheet 5.7	
6	Methods and Devices for Providing Protection – Worksheet 6	
7	Selection of Protective Devices – Worksheet 7	
8	Selection of Devices for Isolation and Switching – Worksheet 8	
9	Design and Layout of Main Switchboards – Worksheet 9.1	
	Switchboard Layout Project – Worksheet 9.2	

References

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- AS/NZS 3017 (Current edition) – Electrical Installations – Testing and Inspection
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Electrical Requirements (2015)
- WA Distribution Connections Manual (4th ed.)
- Electrical Wiring Practice (7th ed.) Pethebridge, K. & Neeson, I.
- Code of Practice for Persons working on or near energised electrical installations

UEENEEG107A Select wiring systems and cables for low voltage general electrical installations

Competency Standard Units

Prerequisite Units

Granting competency in this unit shall be made only after competency in the following units have been confirmed.

UEENEEE101A	Apply Occupational Health and Safety regulations, codes and practices in the workplace
UEENEEE102A	Fabricate, dismantle, assemble of electrotechnology components
UEENEEE104A	Solve problems in d.c circuits
UEENEEE105A	Fix and secure electrotechnology equipment
UEENEEE107A	Use drawings, diagrams, schedules, standards, codes and specifications
UEENEEG006A	Solve problems in single and three phase low voltage machines
UEENEEG033A	Solve problems in single and three phase electrical apparatus and circuits
UEENEEG063A	Arrange circuits, control and protection for general electrical installations
UEENEEG101A	Solve problems in electromagnetic devices and related circuits
UEENEEG102A	Solve problems in low voltage a.c. circuit
UEENEEG106A	Terminate cables, cords and accessories for low voltage circuits

ELEMENT		PERFORMANCE CRITERIA	
1	Prepare to select wiring systems and cables for general electrical installations	1.1	The extent and nature of the electrical installation is determined from job specifications.
		1.2	Safety and other regulatory requirements to which the electrical installation shall comply area are identified, obtained and understood.
		1.3	Cable routes, the route lengths of cables and the conditions in which the wiring system is to operate is determined from job specifications or from consultation with appropriate persons.
2	Select wiring systems and cables for general electrical installations	2.1	Wiring systems are selected for suitability for the environments in which they are to operate.
		2.2	Cable conductor sizes are selected to meet current-carrying capacity requirements and voltage-drop and earth fault-loop impedance limitations.
		2.3	Circuit protective devices are selected to meet requirement for co-ordination with conductor current-carrying capacity.

ELEMENT	PERFORMANCE CRITERIA	
	2.4	Earthing system components are selected to meet requirements of an MEN system.
	2.5	Evidence is obtained that electrical equipment selected complies with safety requirements.
3 Document electrical installation.	3.1	Evidence is obtained from manufacturers/suppliers that electrical equipment selected complies with safety requirements.
	3.2	Reasons for selections made, including calculations, are documented in accordance with established procedures.
	3.3	Electrical installation arrangement and specifications for all selected items are documented in accordance with established procedures and forwarded to appropriate person(s).

Required Skills and Knowledge

KS01-EG107A Electrical Installation – Cable selection and co-ordination

Evidence shall show an understanding of selecting cables and ensuring co-ordination between protection device and conductors in electrical installations that comply with the Wiring Rules, Selection of cables standards and Service Rules to an extent indicated by the following aspects:

T1 Performance requirements - design and safety encompassing:

- harmful effects against which the design of an electrical installation must provide protection.
- performance standards of a correctly functioning electrical installation.
- supply characteristics that shall be considered when designing an electrical installation.
- acceptable methods for determining the maximum demand in consumer's mains and sub-mains.
- AS/NZS 3000 requirements limiting voltage drop in an installation.
- reason for dividing electrical installations into circuits and the factors that shall determine their number and type.
- typical external factors that may damage an electrical installation and that shall be considered in the installation design.
- methods for protecting persons and livestock against direct and indirect contact with conductive parts and the typical application of each.
- acceptable methods of protection against the risks of ignition of flammable materials and injury by burns from the thermal effects of current, in normal service.
- likely sources of unwanted voltages and the methods for dealing with this potential hazard.
- acceptable methods for protecting persons and livestock against injury and property against damage from the effects of over current.
- requirement for protection against fault current.
- requirement for protection against the harmful effects of faults between live parts of circuits supplied at different voltages.
- need for protection against injury from mechanical movement and how this may be achieved.
- features of 'fire rated construction' and how the integrity of the fire rating can be maintained in relation to electrical installation.

T2 Final subcircuit arrangements encompassing:

- factors that shall be considered in determining the number and type of circuits required for an installation.
- daily and seasonal demand for lighting, power, heating and other loads in a given installation.
- number and types of circuits required or a particular installation.
- current requirements for given final subcircuits.
- layout/schedule of circuits for given installations.

T3 Factors affecting the suitability of wiring systems encompassing:

- wiring systems typically used with various construction methods and particular environments.
- installation conditions that may affect the current-carrying capacity of cables.
- external influences that may affect the current-carrying capacity and/or may cause damage to the wiring system.
- AS/NZS 3000 requirements for selecting wiring systems for a range of circuits, installation conditions and construction methods into which the wiring system is to be installed. Note: Wiring systems include cable enclosures, underground wiring, aerial wiring, catenary support, emergency systems, busbar trunking and earth sheath return.

T4 Maximum demand on consumer’s mains/submains encompassing:

- acceptable methods for determining the maximum demand on an installation’s consumer’s mains and submains.
- maximum demand for the consumer's mains for given installations up to 400 A per phase.
- maximum demand for given submains.

T5 Cable selection based on current carrying capacity requirements encompassing:

- installation conditions for a range of wiring systems and applications.
- external influences that require the use of a de-rating factor.
- AS/NZS 3000 requirements for coordination of cables and protection devices.
- AS/NZS 3008 used to select conductor size based on the maximum current requirement for a given installation condition including any applicable de-rating factors.

T6 Cable selection based on voltage drop requirements encompassing:

- AS/NZS 3000 requirements for maximum voltage drop in an installation.
- relevant tables in AS/NZS 3008 for unit values of voltage drop.
- calculation of the expected voltage drop in a given circuit.
- selecting cables to satisfy voltage drop requirements in addition to current carrying capacity requirements.

T7 Cable selection based on fault loop impedance requirements encompassing:

- AS/NZS 3000 requirements for maximum fault loop impedance in an installation.
- relevant tables in AS/NZS 3008 to determine cable impedances.
- calculation of the expected fault loop impedance for a given circuit arrangement.
- selecting cables to satisfy fault loop impedance requirements in addition to current carrying capacity requirements and voltage drop requirements.

T8 Selecting protection devices encompassing:

- acceptable methods of protection against indirect contact.
- AS/NZS 3000 requirements for selecting methods and devices to protect against indirect contact for a range of installation types and conditions.
- coordination between conductors and protection devices to ensures the protection of cables from over heating due to over current.
- possible injuries to persons and livestock from hazards due to a short circuit.
- AS/NZS 3000 requirements for selecting devices to protect against overload current for a range of circuits and loads.
- AS/NZS 3000 requirements for selecting devices to protect against short-circuit current for a range of installation conditions.

T9 Selecting devices for isolation and switching encompassing:

- requirements for the provision of the isolation of every circuit in an electrical installation.
- need for protection against mechanical movement of electrically activated equipment.
- AS/NZS 3000 requirements for selecting devices for isolation and switching for a range of installations and conditions.

T10 Switchboards encompassing:

- AS/NZS 3000 and local supply authority requirements for switchboards.
- tariff structures for the supply of electricity.
- equipment installed at the main switchboards with capacities up to 400 A per phase.
- layout of a main switchboard for an installation supplied with single phase single tariff whole current metering.
- layout of a main switchboard for an installation supplied with single phase multiple tariff whole current metering.
- layout of a main switchboard for an installation supplied with multiphase single tariff whole current metering.
- layout of a main switchboard for an installation supplied with multiphase multiple tariff whole current metering.
- layout of a main switchboard for a multiple tenancy installation with whole current metering.
- layout of a main switchboard, including metering, for an installation supplied with three phase CT metering.
- local supply authority requirements for connection of an electrical installation to the electrical supply system.

G107A Work Performance Tasks:

UEENEEG107A – Select wiring systems and cables for low voltage general electrical installations

1. Performance requirements:

1a. Related to the following elements:

1. Prepare to select wiring systems and cables for general electrical installations.
2. Select wiring systems and cables for general electrical installations
3. Document electrical installations.

1b. For each element demonstrate performance:

- across a representative body of performance criteria,
- on at least 2 occasions,
- autonomously and to requirements,
- within the timeframes typically expected of the discipline, work function and industrial environment.

2. Representative range includes the following:

All listed tasks related to performance across a representative range of contexts from the prescribed items below:

Group No	The minimum number of items on which skill is to be demonstrated		Item List
A.	All of the following:	**Arranging electrical installations**	• Selecting cables • Selecting protection methods • Selecting protection devices • Selecting switchgear and control gear • Selecting earthing components • Selecting a wiring system for a fire pump • Documentation of electrical installation

Workplace Rules:

Rule 1	Follow the instructions
Rule 2	Tolerate ambiguity
Rule 3	Meet your obligations

Note: This information and current details of critical aspects for each competency standard unit (CSU) in this qualification can be found at the Australian Training Standards website www.training.gov.au.

UEENEEG107A Select wiring systems and cables for low voltage general electrical installations

Learning and Assessment Plan

Name of Lecturer: ____

Contact Details: ____

Delivery Mode/s: □ Face to Face □ On-Line □ Blended Delivery □ Other

Using:

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Distribution Connections Manual (4th ed.)
- WA Electrical Requirements (2014)
- Electrical Wiring Practice (7th ed.) Pethebridge, K. & Neeson, I.

Session	Nominal Duration	Program of Work (Topics to be covered)	Primary Reference
1	4 hours	Introduction to UEENEEG107A Recognition of Prior Learning Section 1- Performance of an Electrical Installation	Resource Book
2	2 hours	Section 2 - Methods of Ensuring Safety and Protection Against Damage	Resource Book
3	2 hours	Section 3 - Circuit Arrangements	Resource Book
4	2 hours	Section 4 - Wiring Systems	Resource Book
5	32 hours	Section 5 - Selection of Cables for an Installation	Resource Book
6	2 hours	Section 6 - Methods and Devices for Providing Protection	Resource Book
7	4 hours	Section 7 - Selection of Protective Devices	Resource Book
8	2 hours	Section 8 - Selection of Devices for Isolation and Switching	Resource Book
9	8 hours	Section 9 - Design and Layout of Switchboards	Resource Book
10	2 hours	**Written Assessment**	RSAK – KS01 – EG107A
11	2 hours	**Observed Practical Assessment**	UEENEEG107A Elements

I acknowledge that I have received and read this Learning and Assessment Plan

Student Name:______________________ Signature: _______________________ Date: _________

Lecturer Name	Lecturer Signature	Date

Assessment Strategy

Conditions of Assessment:

Normally learning and assessment will take place in an integrated classroom/ laboratory environment.

It is essential to work through the worksheets and activities in this workbook and follow the guidance of your lecturer. The worksheets and practical activities will provide the required skills and knowledge outlined in this Unit and assist you in achieving competency.

Assessment Methods:

Written Assessment – based on the Require Skills and Knowledge (RSAK). You must achieve a mark of 75% or more in this assessment.

Observed Practical Assessment – based on the Elements and Performance Criteria of this Competency Unit UEENEEG107A. You must achieve a mark of 100% in this assessment.

On-Job-Training:

It is expected that the off-job component of this competency unit will be complemented by appropriate on-job development involving exposure to re-occurring workplace events and supervised experiences. (See Work Performance Tasks.) You are required to log your on-the-job training in your 'Q-Tracker' account.

Sufficiency of Evidence:

In all instances competency is to be attributed on evidence sufficient to show that a person has the necessary skills required for the scope of work. These include:

- Task skills - performing individual tasks
- Task management skills - managing a number of different tasks
- Contingency management skills - responding to irregularities and breakdowns in routines
- Job/role environment skills - dealing with the responsibilities and expectations of the work environment including working with others.

Evidence must demonstrate that an individual can perform competently across the specified range of activities and has the required skills and knowledge underpinning the competency.

LABORATORY SAFETY INSTRUCTIONS

Students working in Laboratories at this campus do so, on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. No circuit is to be plugged in or switched on without specific permission of the lecturer in charge of the class. A circuit must be switched off and tested for zero volts before any connection leads are removed. The DANGER TAG PROCEDURE must be used at all times.
2. Do not leave any circuit switched on any longer than necessary for testing. Do not walk away and leave the circuit switched on.
3. Report any broken, damaged or unserviceable equipment to your lecturer.
4. All of your wiring must be disconnected at the end of each practical class or as each project is completed.
5. Make all connections in a safe manner with an appropriate connecting device. Unshielded 4 mm banana plugs are not to be used for wiring.
6. Switch off, remove the plug from the socket and attach your danger tag to the plug top before working on the project. It is not sufficient to simply turn the supply switch off.
7. When disconnecting your wiring from a connection made under a screw, undo the screw- do not cut the wires off.
8. Observe the correct colour code for all wiring projects.
9. Check your circuit for short circuits with your multimeter before asking your lecturer to switch on. Check the checker before and after EACH check.
10. Skylarking is not permitted at any time.
11. Proper clothing and footwear must be worn at all times when you attend this campus. Thongs, sandals and singles alone are not permitted. **Safety boots or safety shoes must be worn in workshops, laboratories and installation skills areas**.
12. Where a project sheet is issued for a practical project, complete each step in the Procedure before moving on to the next step.
13. Draw all diagrams in pencil so that they can be easily changed or corrected. Mark off each connection on your circuit or wiring diagram as it is made.
14. Check the function and range before taking a reading with a multimeter.
15. Make sure that it is YOUR plug before you insert it into a socket outlet.
16. Always switch a multimeter OFF or to the highest possible AC volts range when you have finished using it.

Student's Signature _________________________ Date: _________________

WORKSHOP SAFETY INSTRUCTIONS

Students working in workshops and installation skills areas at this college do so on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. Personally owned eye protection must be worn AT ALL TIMES. Other safety equipment including hearing protection must be worn when applicable to a particular task.
2. Loose clothing must not be worn when working on fixed or portable machines. Hairnets must be worn where applicable. Clothing must cover the upper arms and body.
3. Enclosed footwear must be worn at all times on this campus. Thongs or sandals are not permitted. **Safety boots or safety shoes must be worn in workshop and installation skills areas**.
4. Tools and safety equipment are issued from the tool store on request. It is your responsibility to ask for the correct item (Size, Type and Tool). Check to see that you have been given the correct item before using it. If in doubt ask your LECTURER, not the storeperson.
5. Report any broken, damaged or unserviceable equipment to your Lecturer. Do not use damaged tools or machines.
6. Clean down the machines immediately after use. All tools must be cleaned before returning them to the store.
7. Skylarking is not permitted at any time.
8. Always use protective vice jaws when cutting off material in a bench vice.
9. Accidents resulting in cuts, abrasions or other personal injury must be reported to your Lecturer immediately - no matter how minor they may seem. A first-aid kit is available in the tool store.
10. Never leave a machine unattended when it is running. Do not allow yourself to be distracted when operating a machine.
11. Read all safety signs and notices and follow the instructions.
12. Do not use a fixed or portable machine unless you have been instructed in its proper use.
13. Read all risk assessment documentation provided (JSAs) and conduct a relevant risk assessment process before performing any task.

Student's Signature ___________________________ Date: __________________

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Danger Tag Procedure

Use of Danger Tags

If you have a practical task to do and there is a possibility that you could be injured if someone turns on the electricity, then you **MUST** fasten a red danger tag to the machine main isolation switch, circuit-breaker or the equipment plug top.

Each danger tag you use must clearly show; your name, your section (class) and the date.

Nobody must operate the danger tagged switch or control point until the job is made safe and the danger tag has been removed.

Your lecturer will check your task before you are allowed to remove your danger tag.

Only the person, who is named on the tag and attached the tag, is allowed to remove it.

Points to Watch

Make absolutely sure the switch/circuit-breaker/plug top is the correct one to tag. If you have any doubts, ask your lecturer.

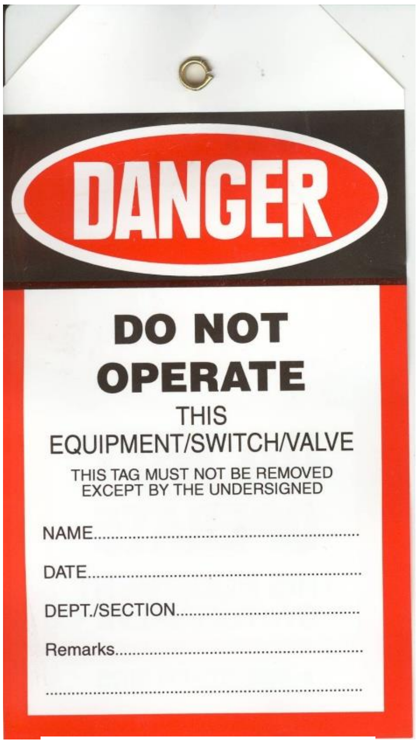

Photo © NMTAFE

Make sure that you have switched the isolator to **OFF** position before you attach your danger tag.

Fasten the danger tag securely.

The purpose of using Danger Tags is to prevent electrical accidents from happening.

Failure to follow Danger Tag Procedures when working on practical activities and practical assessments will result in a ‘**Not yet competent’** comment recorded for this Unit of Competency – UEENEEG107A

Student's Signature _________________________ Date: _________________

Notes

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 1 Introduction	G107A SGB 08/2014

Performance of an Electrical Installation

Task:

Explain the factors that affect acceptable performance of an electrical installation.

Why:

The design of an electrical installation requires consideration of several factors relating to how the installation is required to perform to ensure the safety of persons, property and livestock and meet as a minimum, all mandatory requirements. Installation designers must be aware of these factors so that the installation can be designed accordingly.

It is essential for an electrician to have an understanding of typical methods and devices to protect persons, livestock and property against dangers and damage that may arise in the reasonable use of electrical installations and under fault conditions so that hazards associated with electrical current flow can be avoided.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulations or representations of appropriate installations.

References

* Electrical Wiring Practice (7th ed.) – Volume 1, Pethebridge & Neeson
* Electrical Wiring Practice (7th ed.) – Volume 2 , Pethebridge & Neeson.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1:2017 - Electrical installations. Selection of cables.
* AS/NZS 4836.2001 - Safe working practice on low-voltage electrical installations
* WA Electrical Requirements:2014.
* WA Distribution Connections Manual:2013
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.
* Code of Practice for Persons working on or near energised electrical installations.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 1 Study Guide	G107A SGB 08/2014

Performance of an Electrical Installation

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Clause 1.5 Fundamental principles
Clause 1.6 Design of an electrical installation
Clause 1.7 Selection of electrical equipment

Electrical Wiring Practice (7th ed.) Volume 2

Chapter 5 Electrical Installation Planning
Section 5.1 Factors affecting installation design

WA Electrical Requirements : 2014

Section 9 Special requirements for installations in WA

WA Distribution Connection (4th ed.) : 2013

Section 10.11 Customers' Responsibilities

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this manual.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 1 Summary	G107A SGB 08/2014

Performance of an Electrical Installation

1. Before an electrical installation can be commenced, consideration must be given to the type of installation, what it is intended to do and how it is intended to perform under all anticipated local conditions. The installation must provide protection of persons, livestock and property, it must function properly for the use intended, and it must be compatible with the local electricity distribution system.
2. In an electrical installation the 3 major risks are;

   a. Shock current
   b. Excessive temperatures and
   c. Explosive atmospheres
   (AS/NZS 3000 1.5.1)

   These risks must be assessed so the installation minimizes inconvenience in the event of a fault and facilitate safe operation, inspection, testing and maintenance

3. Typical considerations may include:

   a. The nature of the current – a.c. or d.c.
   b. The number and type of supply conductors.
   c. The available supply voltage(s) and frequency.
   d. The maximum available supply current.
   e. The prospective short circuit current at the main switchboard.
   f. Protection requirements – including RCDs and the type of protective earthing system.
   g. Limitations on the use of electrical equipment.
   h. Anticipated ambient high and low temperatures.
   i. The local environmental conditions.
   j. Local vegetation.
   k. Proximity to the coast or other expanses of water.
   l. Mechanical movement of parts of the installation.
   m. The existence of hazards areas or conditions.
   n. Other local services such as gas or water.
   o. Local supply variations.
   p. Emergency situations that may arise.
   q. Anticipated movement of vehicles.
   r. External influences (See AS/NZS 3000 Clause 3.3).
   s. The maximum demand of the installation.
   t. Voltage drop in parts of the installation.
   u. The number and type of circuits required.

4. Read Electrical Wiring Practice (7th ed.) Volume 2 – Chapter 5

   a. Factors affecting installation design.
   b. Arranging an electrical installation into circuits.
   c. Factors affecting cable selection
   d. Determining maximum demand.
   e. Selection of minimum cable size based on current carrying capacity.

f. Selection of minimum cable size based on volt-drop and fault loop impedance limitations.
g. Short-circuit temperature performance of cables.

5. Read the following sections in AS/NZS 3000:2018 - Wiring Rules:

a. Clause 1.5 Fundamental principles
b. Clause 1.6 Design of an electrical installation
c. Clause 1.7 Selection of electrical equipment

6. Read the following section in WA Electrical Requirements (2014)

Section 9 Special requirements for installations in WA

7. Read the following section in WA Distribution Connections Manual (2013)

Section 10.11 Customers' responsibilities

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 1 Worksheet	G107A SGB 08/2014

Performance of an Electrical Installation

1. State five factors to be considered in the design of an electrical installation.

2. State ten fundamental principles which must be met to ensure the safe operation of an electrical installation.

3. What are three of the electrical supply characteristics which must be determined before the design of a particular installation is commenced?

4. What are the four methods of determining the maximum demand of an electrical installation according to the Wiring Rules?

5. What is the maximum permissible voltage drop at any point in a low voltage electrical installation according to the Wiring Rules?

6. What is the maximum permissible voltage drop at any point in an extra-low voltage electrical installation according to the Wiring Rules?

7. List four of the factors which should be considered when determining the arrangement of circuits to be installed in an electrical installation.

8. List four of the external influences which may need to be considered when designing an electrical installation.

9. What is the minimum cable size for a three phase consumer's mains for a domestic installation according to the WA Electrical Requirements?

10. List three major types of risks that the AS/NZS 3000 requires persons, livestock and property to be protected against.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 2 Introduction	G107A SGB 08/2014

Methods of Ensuring Safety and Protection Against Damage

Task:

Demonstrate an understanding of typical methods of ensuring safety and protection against damage in an electrical installation.

Why:

It is essential for an electrician to have an understanding of typical methods and devices to protect persons, livestock and property against dangers and damage that may arise in the reasonable use of electrical installations and under fault conditions so that hazards associated with electrical current flow can be avoided.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set laboratory tasks.

3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice(7th ed.), Pethebridge, K. & Neeson, I.
* AS/NZS 3000:2018 Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* AS/NZS 4836.2001 - Safe working practice on low-voltage electrical installations
* WA Electrical Requirements:2014.
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.
* Code of Practice for Persons working on or near energised electrical installations.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 2 Study Guide	G107A SGB 08/2014

Methods of Ensuring Safety and Protection Against Damage

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Clause 1.5 Fundamental principles
Clause 3.3 External influences

Electrical Wiring Practice (7th ed.) Volume 1

Section 2.3 Safety of electrical installations and equipment
Section 2.4 Hazards of working with electricity
Section 3.6 Fundamental requirements (Wiring Rules Part 1)

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this manual.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 2 Summary	G107A SGB 08/2014

Methods of Ensuring Safety and Protection Against Damage

1. The Wiring Rules specifies requirements and installation methods intended to ensure the safety of persons, livestock and property against dangers and damage that may arise in the reasonable use of electrical installations. Two major types of risk are identified in Clause 1.5.1:

   a. Electric shock current arising from contact with parts which are live in normal service (direct contact) or parts which become alive under fault conditions (indirect contact).

   b. Excessive temperature likely to cause burns, fires and other injurious effects

2. Read the following sections in AS/NZS 3000:2018 - Wiring Rules

   a. Clause 1.5 Fundamental principles
   b. Clause 1.6 Design of an electrical installation
   c. Clause 1.7 Selection of electrical equipment
   d. Clause 3.3 External influences

3. A general summary of the principles and methods for providing protection, as specified in the Wiring Rules, is given on the following page.

General Summary – Fundamental Principles (AS/NZS 3000:2007 Clause 1.5)

Risks		
Electric shock		Excessive temperatures
Direct contact	Indirect contact	

Type of Protection	**Principles**	**Methods**
Direct contact	Prevent current flowing. Limit current to low value. Use ELV supply.	Insulation. Barriers or enclosures (IP 2X). Obstacles. Placing out of reach. Separated ELV < 50 V (SELV). Protected ELV < 50 V (PELV).
Indirect contact	Prevent current flowing. Limit current to low value. Automatically disconnect supply. Use ELV supply.	Automatic disconnection of supply. Use of double insulation (Class II). Electrical separation. Separated ELV < 50 V (SELV). Protected ELV < 50 V (PELV).
Earth leakage	Prevent shock current flowing.	Install RCD. Prevent direct or indirect contact.
Thermal effects	Screening with suitable materials. Enclosure in arc resistant material.	Screening of flammable materials. Enclosure of equipment. Place in inaccessible position. Guard parts likely to cause burns.
Unwanted voltages	Reduce electromagnetic induction.	Terminate and protect unused conductors.
Overcurrent	Prevent or limit overcurrent.	Automatic disconnection. Limiting current to a safe value and duration.
Fault currents	Adequate conductor size.	Use conductors of adequate size.
Overvoltage	Prevent or limit overvoltage.	Segregation. Installation of overvoltage protection devices.
Mechanical movement	Restrict or control movement.	Devices to disconnect or isolate.
Devices for isolation	Prevent or remove hazards.	Provide isolation device in actives.
Fire isolation	Adequate constructional features.	Maintain fire rated integrity.

General Design Principles (Clause 1.6)		
Protect persons, livestock and property from harmful effects.	Ensure correct functioning of installation – as intended.	Ensure compatibility with electricity distribution system.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 2 Worksheet	G107A SGB 08/2014

Methods of Ensuring Safety and Protection Against Damage

1 List three major types of risks that the AS/NZS 3000 requires persons, livestock and property to be protected against.

2. List six different methods for protecting persons and livestock for basic protection (direct contact).

3. List four different methods for fault protection (indirect contact).

4. Describe three acceptable methods for protection against the risks of ignition from arcs and sparks.

5. Describe one likely source of voltages in unused conductors and the methods for dealing with this potential hazard.

6. List two methods for protecting persons and livestock against injury and property against damage from the effects of overcurrent.

7. What is the main requirement when providing protection for earthing and other conductors against earth fault current.

8. List two methods of providing protection against the effects of abnormal voltages occurring as a result of faults between live parts of circuits supplied at different voltages.

9. One of the general principles is to provide protection against injury from mechanical movement. Describe one method of achieving this.

10. What is the main installation requirement when a wiring system passes through a floor, wall or ceiling that is required to be of 'fire rated construction'?

Notes

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 3 Introduction	G107A SGB 08/2014

Circuit Arrangements

Task:

Demonstrate an understanding of typical methods of arranging circuits to provide satisfactory performance in an electrical installation.

Why:

Electrical circuits must be arranged so that the installation is safe, and provides minimum inconvenience under fault conditions.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set laboratory tasks.

3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice(7th ed.), Pethebridge, K. & Neeson, I.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1:2017 - Electrical installations. Selection of cables.
* AS/NZS 4836:2011 - Safe working practice on low-voltage electrical installations
* WA Electrical Requirements:2014.
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.
* Code of Practice for Persons working on or near energised electrical installations

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 3 Study Guide	G107A SGB 08/2014

Circuit Arrangements

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Clause 1.6 Electrical installation circuit arrangement

Electrical Wiring Practice (7th ed.) Volume 2

Chapter 5 Installation Planning and Design – selecting cables and protective devices
Factors affecting installation design
Arranging an electrical installation into circuits

WA Electrical Requirements (2014)

Section 9 Special requirements for installations in WA

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this manual.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 3 Summary	G107A SGB 08/2014

Circuit Arrangements

1. The Wiring Rules specifies that every installation shall be divided into circuits as necessary to avoid danger and minimise inconvenience in the event of a fault, and facilitate safe operation, inspection, testing and maintenance (see Clauses 1.6.5 & 2.2.1).

2. Safety services shall be capable of maintaining supply to electrical equipment when exposed to fire. Circuits for safety services must be wired separately from the rest of the electrical installation see clause 7.2.2).

3. The number and arrangement of circuits depends on factors such as:

   a. Domestic or non-domestic.
   b. Types of appliances to be installed.
   c. Special areas – such as pools or water features.
   d. Location of internal distribution points.
   e. The intended use of socket outlets.
   f. Foreseeable emergency situations such as smoke alarms.
   g. Maintenance requirements.
   h. Current requirements for specific equipment (such as motors).
   i. Special tariff arrangements.
   j. Loading of circuits.
   k. Seasonal and daily variations in demand such as air conditioners.
   l. Possible fault conditions.
   m. Standing leakage current in particular appliances.
   n. The load on particular circuits.
   o. Special services – such as energy management or safety systems.

4. Most installations contain loads which are seasonal in other words, loads that are used more in one season than another e.g. a heater would be used in winter, an air-conditioner would be used in summer. These loads are taken into account when determining max demand for the installation.
   In the design of an installation it requires a good deal of planning and foresight. The arrangement begins with knowing what the customer requires. The distribution arrangement of circuits fall into several categories like;

   Lighting
   Socket-outlets
   Cooking appliances
   Heating appliances
   Cooling appliances
   Motors
   Auxililiary services, such as indication and control of Safety services.

Table C9 in the wiring rules gives guidance on the loading of points per final sub-circuit.

Example 1:

How many lighting circuits would be required in a house, if the installation consisted of 36 lighting points protected by 10A MCB's.

0.5A per lighting point.

$\frac{10}{0.5}$ = 20 points per 10A MCB

Therefore $\frac{36}{20}$ = 1.8 which is 2 circuits.

Example 2:

How many 10A General Socket outlet circuits would be required in a Factory with air conditioning, if the installation consisted of 36 double, 10A General Socket Outlets, protected by 16A MCB's

1A per socket-outlet.

$\frac{16}{1}$ = 16 socket outlets per 16A MCB

Therefore $\frac{72}{16}$ = 4.5 which is 5 circuits

When designing and connecting an installation we must also remember;

Not to connect high demand appliances to the same circuit,

Provide a separate circuit for equipment that has a current rating of 20A per phase

Provide a separate circuit for essential services.

5. The maximum demand in final sub-circuits is determined by either-

Assessment of the connected load for equipment or by limitation of the current rating of a circuit breaker for multiple pieces of equipment.

Some equipment allows for diversity where the equipment may be less than the full connected load e.g. cooking appliances.

Table C5 provides assessed maximum demand values that may be applied to a final sub-circuit using the energy rating of the cooking appliance or combined energy rating of the cooking appliances

6. Within every switchboard a circuit schedule should be available and prominently displayed to show the following;

The circuit number.
The description of the circuit.
Which phase it's connected to.
The size of the MCB or fuse.
Name of switchboard.

If a distribution board, the origin of supply.

SWITCHBOARD: SB 1 LOCATION: Lecturers office			
No	Circuit Description	Phase	Rating
1	lighting	R	10A
2	GPO’s	W	16A
3	GPO’s	B	16A

7. Read the following sections in AS/NZS 3000:2018 - Wiring Rules

Clause 1.6 Design of an electrical installation.

8. Read Electrical Wiring Practice(7th ed.), Volume 2.

Chapter 5 Installation Planning and Design – selecting cables and protective devices:

Factors affecting installation design
Arranging an electrical installation into circuits

9. Read the following sections in WA Electrical Requirements:2014

Section 9 Special requirements for installations in WA

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 3 Worksheet	G107A SGB 08/2014

Circuit Arrangements

1. List four factors that need to be considered when determining the division of circuits in installations, according to the AS/NZS 3000.

2. According to the wiring rules, what is the minimum number of RCDs that must be installed in domestic or residential installations where RCD protection is required?

3. What type of electrical device could generally be expected to have a high demand in one season but not another?

4. According to AS/NZS 3000, how many 10A General Socket outlet **circuits** would be recommended in a Factory with no air-conditioning, if the installation consisted of 57 double and 10 single, 10A General Socket Outlets, protected by 16A MCB's?

5. According to AS/NZS 3000, how many lighting **circuits** would be recommended in a factory, if the installation consisted of 96 lighting points protected by 10A MCB's.

6. According to Table C5 what is the maximum demand of a 9kW cooking range?

7. According to AS/NZS 3000, name 2 reasons why installations must be divided into circuits?

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 4 Introduction	G107A SGB 08/2014

Wiring Systems

Task:

Demonstrate knowledge of wiring systems suitable for a range of electrical installation.

Why:

Electrical installations typically consist of more than one type of wiring system. An electrician needs to be aware of the types of wiring system so that he/she can select the ones most appropriate to the given conditions.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set tasks.
3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice (7th ed.), Pethebridge, K. & Neeson, I.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1:2017 - Electrical installations. Selection of cables.
* AS/NZS 4836.2011 - Safe working practice on low-voltage electrical installations
* WA Electrical Requirements:2014.
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.
* Code of Practice for Persons working on or near energised electrical installations.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 4 Study Guide	G107A SGB 08/2014

Wiring Systems

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Section 1 Scope, application and fundamental principles
Section 3 Selection and installation of wiring systems

Electrical Wiring Practice (7th ed.) Volume 1.

Chapter 7 Wiring and Cabling Systems

AS/NZS 3008.1.1 - Electrical installations. Selection of cables.

Clause 3.4 Installation conditions

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this manual.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 4 Summary	G107A SGB 08/2014

Wiring Systems

1. A wiring system is an arrangement of electrical conductors which provide a path for the current from a voltage source to a consuming device. Most extra-low (not exceeding 50 V a.c.) and low voltage (exceeding 50 V but not exceeding 1000 V a.c.) installations consist of insulated cables run in some type of enclosure, or supported in such a way as to provide protection against electric shock or overheating. Most completed installations consist of more than one type of wiring system.

2. The selection of a type of wiring system for a particular part of an installation requires consideration of the following main factors:

   a. Adequate protection against electric shock.

   b. Protection against external influences and environmental conditions such as mechanical damage, local heat sources, or exposure to the weather. See AS/NZS 3000:2018 Clause 3.3.

   c. Mutual detrimental influences such as heating of adjacent cables, or electrical interference affecting data or communications cables or equipment.

   d. Selection of conductors to satisfy current carrying capacity, voltage drop and other minimum size requirements.

   e. Reliability and electrical continuity of connections, joints and terminations.

   f. Identification of conductors and enclosures (by colour or other means).

   g. Protection against fire and the spread of fire.

   h. The type of building or structure.

   i. The type and amount of mechanical protection required for the cables.

   j. The appearance of the wiring system.

   k. The accessibility of the wiring.

   l. The cost of the installation.

   m. Future alterations which may be required.

   n. Special requirements, such as the presence of moisture, water, flammable materials, chemicals, explosive gases or explosive dust.

   o. The normal operating voltage of the installation.

   p. The amount of ventilation available.

   q. Specific regulatory requirements - such as on construction sites (See AS 3012 Clause 8.1).

3. The most commonly used wiring systems/cables are outlined below, using terminology found in the Wiring Rules and other relevant publications. The detailed requirements for most systems are contained in the Wiring Rules - see Section 3.

a. **Aerial Wiring Systems** Insulated or bare cables run in air and supported on suitable poles and associated equipment.

b. **Armoured Cables** Cables with wire armouring to protect the internal conductors from mechanical damage.

c. **Bare Wiring** Bare live cables installed on insulated supports in locations where they are not generally accessible (No longer supported by the AS/NZS 3000 Wiring Rules).

d. **Busbars** Large bare or covered solid copper or aluminium rectangular conductors for carrying large currents - typically behind large switchboards.

e. **Busways** Solid copper or aluminium conductors rigidly supported in an overhead insulated enclosure, with plug-in access points at intervals.

f. **Cable Trays** Galvanised perforated steel trays used to support insulated sheathed cables, usually in areas not likely to be disturbed.

g. **Catenary Supported Cables** Insulated and sheathed cables run in air clipped to a stranded galvanised steel wire strung between two anchor points.

h. **Ducts** A square or rectangular enclosure for large insulated cables.

i. **Festoon Lighting** Specially manufactured double insulated lampholders attached to flat sheathed cable in such a way that sharp pins penetrate the insulation and sheathing during installation to make contact with the conductors within. Commonly referred to as 'party lights'.

j. **Flat Cables** Cables in which the insulated conductors are manufactured side-by-side, usually requiring special insulation displacement connectors. Commonly used in extra-low-voltage data cabling with up to about 25 cores.

k. **Flexible Metallic and Non-metallic Conduits** Flexible circular pipes with associated accessories. Used as an enclosure for insulated cables.

l. **Flexible Cords** A special type of flexible insulated and sheathed cable suitable for connecting to portable electrical devices. Available in a single insulated form typically used for internal wiring in machines.

m. **Mineral Insulated Metal Sheathed (MIMS) Cables** Between 1 and 7 single strand copper conductors embedded in a compressed insulating powder inside a tubular copper sheath. Can be covered with an outer PVC serving. Requires special accessories for terminating.

n. **Neutral Screened Cables** Insulated and sheathed cables with an outer screen of conducting material suitable for connecting to the neutral.

o. **Open Wiring** Surface mounted insulated cables open to view and supported on insulated cleats.

p. **Rigid Metallic and Non-metallic Conduit** Rigid circular pipes with associated accessories. Used as an enclosure for insulated cables.

q. **Sheathed Cables** Single insulated single core or multi-core cables enclosed in an insulated sheath to provide double insulation.

r. **Track Lighting** Extruded aluminium channel with an internal insulating material containing the active and neutral conductors. It has plug-in facilities along its entire length - for use with associated accessories.

s. **Trailing Cables** Sheathed flexible cords and cables designed for use with moving machinery.

t. **Trunking** A metallic or non-metallic square or rectangular trough for housing insulated cables.

u. **Undercarpet Wiring** Special flat cable designed to be installed under a carpet.

v. **Underground Wiring** Three wiring systems (Category A, B and C) for installing cables underground under various conditions.

w. **Unsheathed Cables** Single insulated flexible cord or flexible cable intended for installation in a protective enclosure.

4. The current carrying capacity of a wiring system can be affected by certain external influences which are listed in AS/NZS 3008 Clause 3.5.

This cable current carrying capacity will be corrected with a de-rated or up-rated factor from tables 26 to 30 in AS/NZS 3008.

When selecting a wiring system it must perform the following function with the safe design and operation of the electrical installation according to AS/NZS 3000 Clause 3.1.2.

(a) Protect against physical contact with live parts by durable insulation materials or by placing live parts out of reach.
(b) Satisfy current-carrying capacity, voltage drop and other minimum size requirements for conductors.
(c) Provide reliability and electrical continuity of connections, joints and terminations.
(d) Provide adequate strength of supports, suspensions and fixings.
(e) Suit intended use, including applications requiring a particular type of wiring system, e.g. fire-resistance, explosion protection, safety services.
(f) Protect against mechanical damage, environmental and other external influences by enclosure or other means.

Particular care needs to be taken when repairing or modifying an existing wiring system because it is possible for terminals or parts to be alive for some unexpected reason - such as incorrect connections, faulty components or damaged wiring.

TEST BEFORE YOU TOUCH

5. **General Installation Processes**

Installation of wiring systems involves several inter-related activities that are performed at appropriate times as the work progresses. In general the processes are those involved in most other electrical work and include:

#	Activity
1	Appropriate personnel are consulted
2	Materials are obtained
3	Preparatory work is checked
4	Tools and equipment are obtained
5	OH&S procedures are followed
6	Isolation is checked
7	Unplanned events are responded to
8	Ongoing checks of quality of work are undertaken
9	Inspection, testing and commissioning is completed
10	Work completion is notified

6. Read the following sections in AS/NZS 3000:2018 - Wiring Rules

Section 1 Scope, application and fundamental principles
Section 3 Selection and installation of wiring systems
Table 3.1 Cable types and their application in wiring systems

7. Read the following section in AS/NZS 3008.1.1 - Electrical installations. Selection of cables:

Clause 3.4 Installation conditions
Clause 3.5 External influences on cables

8. Read the following chapters in Electrical Wiring Practice (7th ed.) Volume 1:

Chapter 4 Cables, connections and terminations
Chapter 7 Wiring and cabling systems.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 4 Worksheet	G107A SGB 08/2014

Wiring Systems

1. Describe four different types of wiring system and give a typical example of where each one could be used.
2. What is the main potential safety hazard when modifying or repairing an existing wiring system?
3. Name four of the general external influences which can cause damage to electrical cables in an installation? Give the AS/NZS 3000 Clause number.
4. Name four of the external influences which can raise or lower the current rating of a cable in an installation and what is the corresponding Table number? Give the AS/NZS 3008 table Numbers.
5. Name four factors which must be considered when selecting a wiring system for a particular installation, according to the AS/NZS 3000?
6. Name four general installation conditions specified in the AS/NZS 3008?

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 5 Introduction	G107A SGB 08/2014

Selection of Cables for an Installation

Task:

To select optimum cables for given circuits based on current-carrying capacity, voltage drop limitations, fault loop impedance requirements, installation condition and external influences.

Why:

All cables in an electrical installation must be able to operate safely under normal operating conditions and anticipated fault conditions.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set tasks.

3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice (7th ed.) - Volumes 1&2 , Pethebridge & Neeson.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1:2017 - Electrical installations. Selection of cables.
* WA Electrical Requirements:2014.
* AS/NZS 4836.2011 - Safe working practice on low-voltage electrical installations
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.
* Code of Practice for Persons working on or near energised electrical installations

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 5 Study Guide	G107A SGB 08/2014

Selection of Cables for an Installation

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 - Wiring Rules

Clause 1.5	Fundamental principles
Clause 1.6	Design of an electrical installation
Section 3	Selection and installation of wiring systems
Appendix B	Circuit Protection Guide
Appendix C	Maximum Demand and Calculations

Electrical Wiring Practice (7th ed.) – Volume 2 Chapter 5

Section 5.3 Factors affecting cable selection.

AS/NZS 3008.1.1:2017 - Electrical installations. Selection of cables.

Clause 3.4	Installation conditions
Clause 3.5	External influences on cables
Section 4	Voltage drop

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this manual.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 5 Summary 5.1	G107A SGB 08/2014

Selection of Cables for an Installation

1. The selection of optimum cables for a given circuit must be based on several considerations, including:

    a. The maximum current to be carried by the cable (or the maximum demand) under normal operating conditions.
    b. The installation conditions.
    c. The type of enclosure.
    d. The ambient temperature.
    e. The maximum temperature rating of the cable insulation.
    f. The presence of thermal insulation materials.
    g. How the cables are grouped.
    h. The voltage drop in the circuit
    i Fault loop impedance requirements.
    j. The type of material used as the conductor.
    k. The type of protection provided for the circuit.
    l. Regulatory requirements applying to the specific type of installation.
    m. The short circuit performance of the cable under fault conditions.
    n Other external influences on cables, such as depth of laying,

2. In general, the current carrying capacity of a cable must not be less than the maximum demand of the circuit, and the maximum demand current is governed by the circuit protection device. Determination of the maximum demand of circuits is covered later in this module. AS/NZS 3000 and AS/NZS 3008.1.1 specify minimum requirements in terms of acceptable performance, such as:

2a. The current carrying capacity and voltage drop for cables is given in AS3008.1 (Cables for alternating voltages up to and including 0.6/1 kV).

2b. Table 1 of AS/NZS3008.1 gives the limiting temperatures for insulated cables. Note that the maximum operating temperature for V90 is 75^0 under normal conditions.

2c. Tables 3(1) to 3(4) give the schedule of installation methods. These tables are used as a guide as to the table required for choosing cables.

2d. Tables 4 to 21 of AS/NZS 3008.1 give the current carrying capacities for various cables and flexible cords.

2e. Tables 22 to 26 give the de-rating factors for various grouping combinations.

2f. Tables 27 to 29 of AS/NZS3008.1 give the rating factors for variations in ambient temperatures and variations in depth of laying of cables, thermal resistivity of soil and effects of direct sunlight.

Current-Carrying Capacity

3. The current-carrying capacity of any cable is the maximum continuous current that a cable can carry without exceeding its maximum permissible temperature (see AS/NZS 3000 Table 3.2 and AS/NZS3008.1.1 Table 1). In general, the current carrying capacity of a cable must not be less than the maximum demand of the circuit, and the maximum demand current is governed by the circuit protection device. In circuits which have a high current or long route length consideration of voltage drop is critical.

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SELECTION OF CABLES FOR AN INSTALLATION

1. What is the maximum current carrying capacity of the following cable? Give the AS3008 Table No.

Installation:	Domestic
Size:	$1mm^2$
Type:	V75 TPS copper final sub circuit
Circuits:	One
Enclosure:	Unenclosed, clipped to the side of a ceiling joist
Protection:	MCB
Phases:	1
Temperature:	Up to 40ºC

Answer.

2. What is the maximum current carrying capacity of a single $1mm^2$ V75 copper TPI final sub circuit in a three phase circuit protected by HRC fuses and enclosed in air? Give the AS 3008 table No.

Answer.

3. What is the maximum current carrying capacity of the following cable? Give the AS3008 table No.

Installation:	none- domestic
Size:	$2.5mm^2$
Type:	V75 TPS copper final sub circuit
Circuits:	Bunched group of four
Enclosure:	Enclosed in air
Protection:	MCB
Phases:	3
Temperature:	Up to 40ºC

Answer.

4. What is the maximum current carrying capacity of $2.5mm^2$ V75 copper TPS cable in a single final sub circuit protected by a circuit breaker and installed in direct contact with a ceiling in the roof space of a domestic installation? Give the AS3008 Table No.

Answer.

5. Complete the following Cable Selection table. Make valid assumptions for detail not provided.

6. Complete the Three attached Cable Selection sheets. Make valid assumptions for detail not provided.

In the following Table find AS/NZS 3008.1 references.
Questions 1 & 2 are requiring information from the Current Carrying Capacity tables.
Questions 3, 4, 5, 6 & 7 require information from the De-rating Factor tables

Cable Selection Table

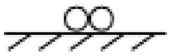
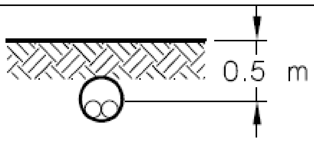
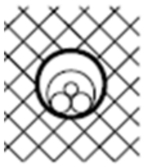
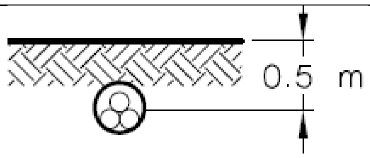
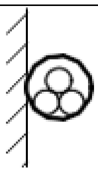
	Installation (protection by ACB)	Installation conditions	AS 3008 Table No.	Column No.
1	A single circuit of 2.5mm²TPI cable in rigid PVC conduit. Partially surrounded by thermal insulation.			
2	A single 1mm²TPS lighting circuit in a domestic ceiling clipped to the joists.			
3	Three separate TPI circuits installed in one rigid PVC conduit in a factory.			
4	Four TPS cables lying flat on open cable tray in the ceiling of a shopping centre.			
5	Eight circuits in one rigid PVC conduit installed on an open concrete wall			
6	Five TPS circuits laid flat touching on a cable tray.			
7	Three TPS circuits cable tied to a catenary wire indoors in a factory			

In the Table ABOVE Find from AS3008 the following:-

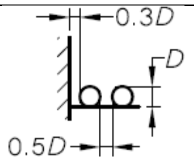
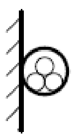
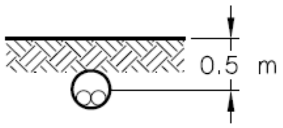
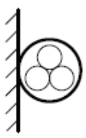
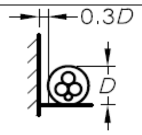
Questions 1 and 2 require information from the Current Carrying Capacity tables.

Questions 3, 4, 5, 6 and 7 require information from the De-rating Factor tables.

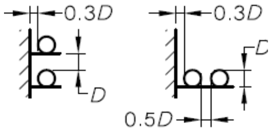
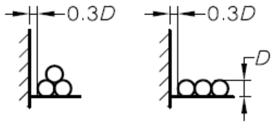
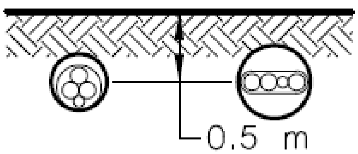
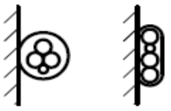
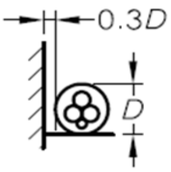
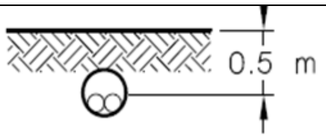
SHEET 1

	Installation	Method of installation	Table No	Column No	Derating Table	Cable
1	 V75 SDI CABLES ONE CIRCUIT COPPER CONDUCTORS	UNENCLOSED TOUCHING IN A VENTILATED TRENCH LOAD: 60AMPS				
2	 V-90 HT TPI CABLES ONE CIRCUIT COPPER CONDUCTORS	ENCLOSED IN CONDUIT IN AIR CLIPPED TO A CEILING LOAD: 45 AMPS				
3	 V75 TPI CABLES ONE CIRCUIT (WITH EARTH) COPPER CONDUCTORS	IN PVC CONDUIT UNDER GRASSED AREA BURIED 500mm DEEP LOAD: 70 AMPS				
4	THERMAL INSULATION  V75 TPS CABLE ONE CIRCUIT (WITH EARTH) COPPER CONDUCTORS	ENCLOSED IN THERMAL INSULATION COMPLETELY SURROUNDED LOAD: 25 AMPS				
5	 V90 TPI CABLES ONE CIRCUIT (WITH EARTH) COPPER CONDUTORS	ENCLOSED UNDERGROUND BURIED 500 mm DEEP LOAD: 223 AMPS				
6	 V75 TPI CABLES ONE 3 PHASE CIRCUIT	ENCLOSED CLIPPED TO A WALL IN AIR LOAD: 123 AMPS				

SHEET 2

	Installation	Method of installation	Table No	Column No	Derating Table	Current
1	 V75 TPS CABLE ONE CIRCUIT COPPER CONDUCTORS	UNENCLOSED PARTIALLY SURROUNDED CABLE SIZE: 6mm²				
2	 V75 SDI CABLES COPPER CONDUCTORS	UNENCLOSED SPACED ON A PERFORATED CABLE TRAY CABLE SIZE: 16mm²				
3	 V90 TPI CABLES SINGLE CIRCUIT COPPER CONDUCTORS	ENCLOSED CABLES IN PVC CONDUIT IN AIR CABLE SIZE: 300mm²				
4	 ELASTOMER CABLES (R-HF 110) COPPER CONDUCTORS 3 CIRCUITS	UNDERGROUND IN PVC CONDUIT BURIED 500mm DEEP CABLE SIZE: 4mm²				
5	 MIMS 1/1KV 3 CORE 2. 5mm² PVC SERVED COPPER CONDUCTORS 4 CIRCUITS	CLIPPED DIRECT TO A WALL TOUCHING IN AIR 40º C AMBIENT TEMPERATURE CABLE SIZE: 2.5mm²				
6	 SINGLE CIRCUIT V75 FOUR CORE TPS 0.6/1KV CABLE COPPER CONDUCTORS	SUSPENDED FROM A CATENERY WIRE IN AIR CABLE SIZE: 35mm²				

SHEET 3

	Installation	Method of installation	Table No	Column No	Derating Table	Cable
1	 V75 SDI CABLES ONE CIRCUIT COPPER CONDUCTORS	UNENCLOSED SPACED IN CLEATS LOAD: 82 AMPS				
2	 V90-HT SDI CABLES ONE CIRCUIT ALUMINIUM CONDUCTORS	UNENCLOSED TOUCHING ON A PERFORATED CABLE TRAY LOAD: 200AMPS				
3	 V75 TPS CABLE ONE CIRCUIT COPPER CONDUCTORS	IN PVC CONDUIT UNDERGROUND BURIED 500mm DEEP LOAD: 82 AMPS				
4	 V75 FOUR CORE + EARTH 3 PHASES + NEUTRAL + EARTH TWO CIRCUITS COPPER CONDUCTORS	UNENCLOSED TOUCHING FIXED UNDER A CEILING LOAD: 58 AMPS				
5	 V75 TPS SWA CABLE ONE 3 PHASE CIRCUIT COPPER CONDUCTORS	UNENCLOSED TOUCHING FIXED TO PERFORATED CABLE TRAY IN THERMAL INSULATION FOR 250mm ONLY LOAD 58AMPS				
6	 ONE CIRCUIT ELASTOMER CABLES (R-HF-110) COPPER CONDUCTORS	UNDERGROUND IN PVC CONDUIT BURIED 500mm DEEP LOAD 35 AMPS				

Notes:-

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 5 Summary 5.2	G107A SGB 08/2014

Maximum Demand of Consumers Mains and Sub-mains

1. AS/NZS 3000:2018 defines three general types of circuits in electrical installations:

   a. Consumer mains.
   b. Sub mains.
   c. Final sub-circuits

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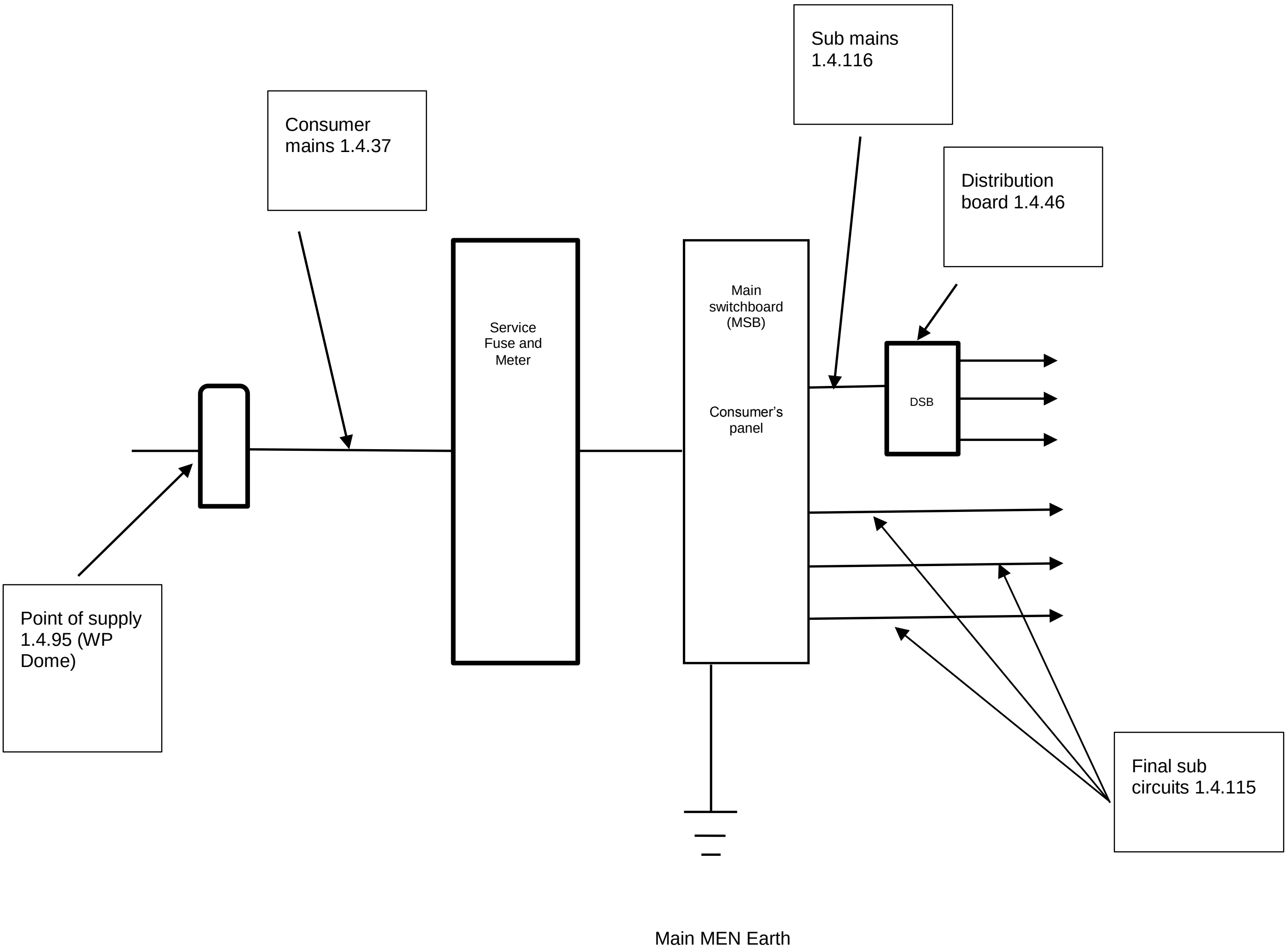


2. The consumer's mains (AS/NZS 3000 Clause 1.4.37) are the cables from the point of supply to the main switchboard. Sub-mains are cables which originate at a switchboard and supply another switchboard. Final subcircuits are cables which originate at a switchboard and terminate at a 'point' such as a lighting point, a socket outlet or the terminals of an appliance.

3. Single phase consumer's mains require two conductors (active and protective earth/neutral) and three phase consumer's mains require four conductors (three phases and a protective earth/neutral). Final subcircuits require active(s), neutral and an earthing conductor.

Maximum Demand in Mains and Sub-mains

4. Maximum demand is the name given to the maximum current likely to be drawn by an entire installation, described as ‘after diversity maximum demand’(or part thereof) for the purposes of determining the cable size and protection requirements. Maximum demand is not the sum of the current which would be flowing if all circuits were loaded to their maximum, because it is unlikely that all devices would be switched on at the same time.

5. Maximum demand of mains and sub-mains can be determined in four ways -by calculation, by assessment, by measurement or by limitation (See AS/NZS 3000 Clause 1.6.3 & 2.2.2). The general method used in this module is calculation.

6. Calculation of maximum demand in mains and sub-mains requires the use of different Tables in AS/NZS 3000, depending on whether the installation is domestic or non-domestic (See Tables C1 and C2). Calculation of maximum demand in mains and sub-mains is not the same as calculation of maximum demand in final subcircuits.

7. Most wiring systems described in AS/NZS 3000 may be used for consumer's mains, with exceptions as given in Clause 3.9.7.1.2.

8. In domestic installations the most common wiring system is TPS cable installed in air.

Calculating Maximum Demand in Mains

9. For the purposes of calculating the maximum demand in mains and sub-mains, each type of load is classified in a 'Load Group' - see AS/NZS 3000 Tables C1 and C2.

10. The process of calculating maximum demand involves grouping the given loads into the categories in Table C1 or C2 and applying the relevant factor to each to determine the maximum demand current. In multiphase installations each phase must be considered separately. The maximum demand for each phase is the sum of the currents in each load group. The total calculated maximum demand is the current in the highest loaded phase.

11. The size of the cable used for the mains is the minimum size of cable which has the required current carrying capacity under the given installation conditions, or the minimum specified in AS/NZS 3000, whichever is greater.

12. In order to calculate maximum demand it is desirable to show the contributing load groups in a table. When preparing a maximum demand table the loads should be arranged in the order in which they appear in the relevant table in AS/NZS 3000 and all calculations should be shown - to make it easier to check. It is essential to read the footnotes to the table in AS/NZS 3000 where applicable. Appendix C of AS/NZS 3000 gives samples of maximum demand calculations.

13. **Example 1** Calculate the maximum demand for the following single phase 240 volt single domestic installation.

The installation consists of:

36 indoor lighting points
2 single 10 amp general purpose socket outlets
12 double 10 amp general purpose socket outlets
2 ceiling mounted exhaust fans (60 W each)
1 15 A socket outlet for a dishwasher
1 9 kW single phase cooking range
1 3.6 kW single phase storage water heater

Maximum Demand Calculation Table (Single Phase)

Load Group	Load (Domestic)	Remarks	Calculations	Contribution in amps
A(i) Table C1	38 lighting points (36 lights and 2 exhaust fans)	3 A for 1-20 points + 2 A for each additional 20. Column 2 See Footnote e	3 A + 2A	5 A
B(i)	26 GPOs (12 doubles and 2 singles)	10 A for 1-20 points + 5 A for each additional 20 points or part thereof. See Footnote h	10+5 A	15 A
B(ii)	1 15 A socket outlet	10 A		10 A
C	9 kW cooking range	9000/240 = 37.5 A	50% of 37.5 = 18.75 A	18.75 A
F	3.6 kW HWS	Full load current. (See Amendment 6/97)	3600/240 = 15 A	15 A
			Maximum demand in the mains:	63.75 A

Note: A GPO is a 240 volt 10 amp three flat pin socket-outlet.

14. The maximum demand in the above installation is 63.75 amps, so the consumer's mains have to be capable of carrying that current under the particular installation conditions which apply to the type of wiring system chosen.

15. Calculation of maximum demand in non-domestic installations is the same basic process as for domestic installations, except that a different table in AS/NZS 3000 is used - Table C2.

Maximum Demand in Three Phase Installations

16. The process of calculating maximum demand for mains and sub-mains in three phase installations is similar to the process used for single phase installations, except that the load has to be 'balanced' so that the calculated current in each of the three phases is a close as possible to being the same. Balancing of the current is done after the maximum demand for each load group has been determined.

17. **Example 2** Calculate the maximum demand of the heaviest loaded phase for the following three phase 415 volt factory installation.

48 twin 36 W indoor fluorescent lighting points (0.5 amps each)
4 single 10 amp general purpose socket outlets
16 double 10 amp general purpose socket outlets
6 three phase 15 A four pin socket outlets
4 5 kW three phase lathe motors rated at 10 amps each
1 3.6 kW single phase storage water heater
3 12 amp 1 phase permanently installed reverse cycle air conditioners

Maximum Demand Calculation Table (Three Phase)

Load Group	Load (Factory)	Remarks (Table C2)	Calculations	Contribution per phase (amps)		
A	48 lighting points	Full connected load. Table 2.4, Column 3.	48 x 0.5 = 24 amps	12	12	
B(ii)	36 GPOs 12/phase (16 doubles and 4 singles)	1000 for first + 100 W each for remainder. (20 actual points)	1000 + 11 x 100 = 2100/240 = 8.75 A/phase	8.75	8.75	8.75
B(iii)	6 three phase 15 A socket outlets	Full load current of highest + 75 % of remainder	15 + (75% of 15 x 5) = 72 A	72	72	72
C	3 single phase air conditioners	Full load current of highest + 75 % of remainder	1 per phase	12	12	12
D	4 10 amp three phase motors	Full load of highest + 75 % of next + 50% of remainder	10+7.5 + (2 x 5) = 27.5 A	27.5	27.5	27.5
G	3.6 kW HWS	Full connected load	3600/240 = 15 A			15
		Maximum demand in each phase (in amps):		132.25	132.25	135.25
		Maximum demand of heaviest loaded phase:				135.25

Note: A GPO is a 240 volt 10 amp three flat pin socket-outlet.

Note: Three phase loads should have approximately the same current in each of the three phases. Single phase loads which can be connected to separate final subcircuits (such as lights and single phase socket outlets) can be distributed across more than one phase to balance the load as much as possible.

18. The examples given above relate to specific types of domestic or non-domestic installation. If an installation is of another type (such as a block of 18 home units or a motel), the appropriate column in the relevant table would have to be used to determine the maximum demand.

Multiple Domestic Installations

19. In the case of multiple domestic living units the calculation of maximum demand usually requires consideration in two parts - loading associated with individual living units and loading of shared facilities such as public lighting, communal laundries, lifts and so on. Columns 3, 4 and 5 of Table C2 must be used in such installations.

Alternative calculation method for non-domestic installations

20. An alternative calculation method may also be used for commercial and light industrial applications. This method is based on experience and energy consumption figures for different types of occupancy within installations C2.4.3

AS 3006 Requirements

21. AS 3006 (Adequate Electrical Installations in Domestic Premises) requires that the maximum demand for the consumers mains in an 'all electric' single domestic dwelling be increased by a factor of 1.25 times the calculated value. An 'all electric' dwelling is defined as one in which electricity is the only energy service to the dwelling (See AS 3006 Note: A GPO is a 240 volt 10 amp three flat pin socket-outlet. Clause 4.1).

Size and Type of Consumer's Mains Cables

22. The size and type of cable required for the mains in an installation depends on factors such as installation conditions, voltage drop and local requirements as well as the maximum demand. Selection of cables is covered later in this module.

24. The minimum permissible current carrying capacity for consumers mains in single domestic installations in WA is 63 amps for single phase and 32 amps for three phase (see WA Electrical Requirements Section 9.2)

Circuit Protection

25. The most common types of circuit protection for sub-mains and final sub-circuits are:

    a. Miniature Circuit breakers
    b. High rupturing capacity (HRC) fuses.

26. In general, circuit breakers are the most convenient type of circuit protection device because they are accurate, reliable and easily reset after a fault has been cleared. Semi-enclosed rewirable fuses are in use in many older existing installations, but they are no longer acceptable for adequate circuit protection in new installations.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 5 Worksheet 5.2	G107A SGB 08/2014

Maximum Demand of Consumer's Mains and Sub-mains

1. Calculate the maximum demand for the following single phase 240 volt single domestic installation. Note: A sample calculation sheet is given at the end of this Work Sheet.

    24 lighting points
    3 single 10 amp general purpose socket outlets
    10 double 10 amp general purpose socket outlets
    2 ceiling mounted exhaust fans (60 W each)
    1 15 A socket outlet
    1 10 kW cooking range
    1 4.8 kW storage water heater

2. Calculate the maximum demand for the following single phase 240 volt single domestic installation.

    2 ceiling mounted exhaust fans (60 W each)
    2 single 10 amp general purpose socket outlets
    16 double 10 amp general purpose socket outlets
    1 8 kW single phase cooking range
    1 15 A socket outlet for a dishwasher
    32 indoor lighting points
    1 3.6 kW single phase storage water heater
    1 2400 W wall mounted strip heater

3. Calculate the maximum demand of the heaviest loaded phase for the following three phase 415 volt boarding house installation.

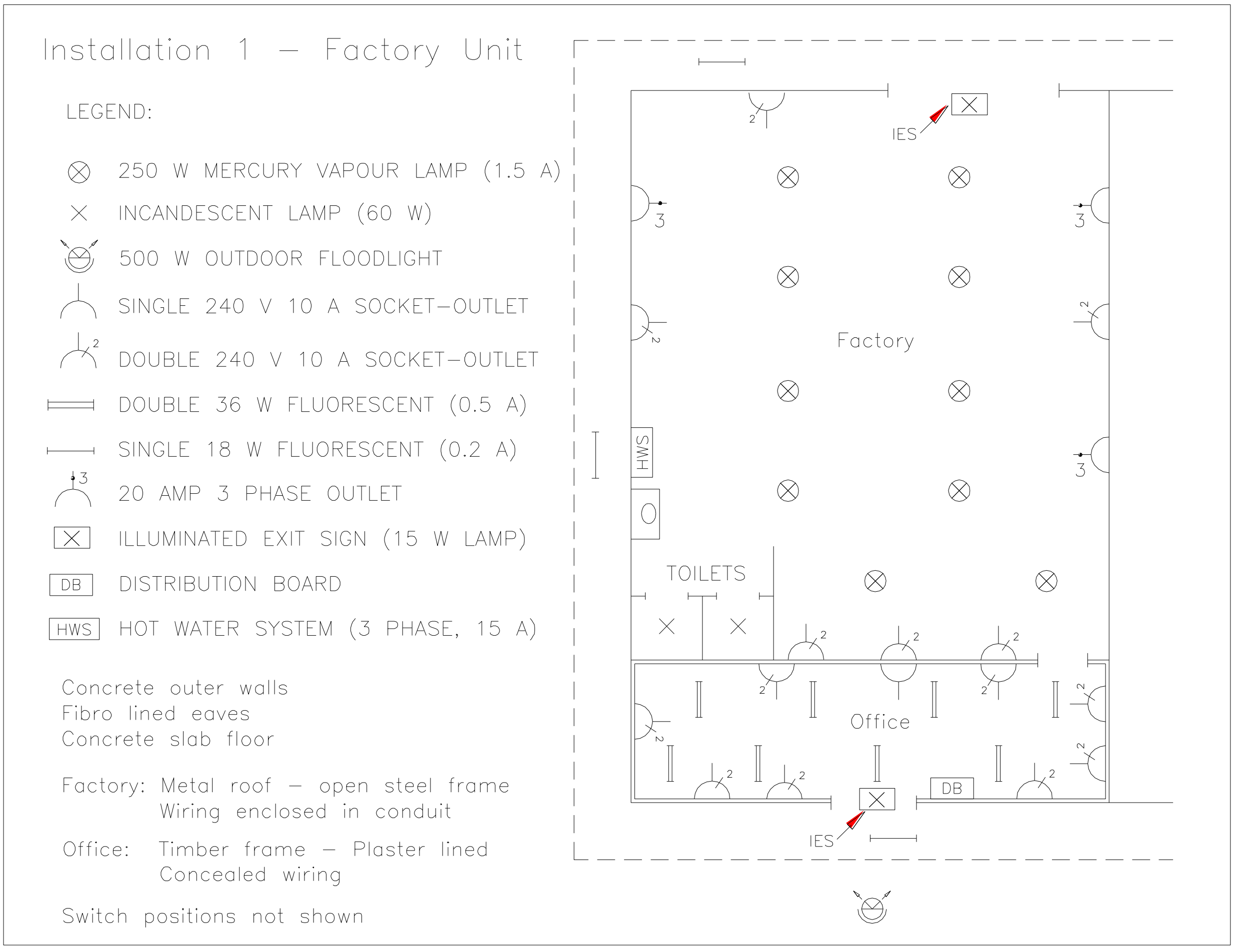
    5 single 18 W indoor fluorescent lighting points (0.2 amps each)
    20 twin 36 W indoor fluorescent lighting points (0.6 amps each)
    25 60 W indoor incandescent lighting points
    5 single 240 V 10 amp general purpose socket outlets
    20 double 240 V 10 amp general purpose socket outlets
    5 15 watt gas oven lights
    5 60 watt ceiling-mounted exhaust fans
    5 3.6 kW single phase storage water heaters
    5 12 amp 1 phase permanently installed reverse cycle air conditioners

4. Calculate the maximum demand of the heaviest loaded phase for the following three phase 415 volt factory installation which does not have permanently connected air conditioning equipment.

   3 3.6 kW storage hot water heaters
   42 Twin 36 W fluorescent lights (0.5 amps each luminaire)
   3 60 W ceiling mounted exhaust fans
   4 250 W outdoor lights
   10 single 10 amp 240 V general purpose socket outlets
   6 15 amp three phase socket outlets
   2 10 amp three phase water pump motors
   1 15 amp three phase lift motor
   1 10 amp three phase fan motor
   20 double 10 amp general purpose single phase socket outlets

5. What is the most suitable circuit protection device for a 32 amp submain? Give reasons for your answer.

6. Calculate the maximum demand of the heaviest loaded phase for the following three phase 415 volt factory installation. Make valid assumptions for any detail not provided.



Sample Maximum Demand Calculation Sheet (Single or Three Phase)

Maximum Demand Calculation Table (Single or Three Phase)

Load Group	Load	Remarks	Calculations	Contribution per phase (amps)		
				R	W	B

Sample Maximum Demand Calculation Sheet (Single or Three Phase)

Maximum Demand Calculation Table (Single or Three Phase)

Q1)

Load Group	Load	Remarks	Calculations	Contribution per phase (amps)		
				R	W	B
A1	24 lights 2 ceiling fans Total 26	3A for 1-20 + 2A for ea. Additional 20	3 + 2 = 5A	5		
B1	3 single & 10 double socket outlets Total 23	10A for 1-20 + 5A for ea. additional 20	10 + 5 = 15A	15		
Bii	15A socket outlet	10A	10A	10		
C	10kW range	50% connected load	10 000÷240 =41.67x (50÷100) =20.8A	20.8		
F	4.8kW storage HWS	Full Load	4 800÷240 =20A	20		
			Maximum demand =	70.8A		

Sample Maximum Demand Calculation Sheet (Single or Three Phase)

Maximum Demand Calculation Table (Single or Three Phase)

Load Group	Load	Remarks	Calculations	Contribution per phase (amps)		
				R	W	B

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 5 Summary 5.3	G107A SGB 08/2014

Voltage Drop in Cables

Voltage Drop

1. Electrical supply authorities try to maintain the voltage at the consumer's terminals as near as possible to the specified voltage. However, some allowance must be made for the drop in electrical pressure between the start and finish of a cable run of wiring. This drop in electrical pressure is known as 'volt drop' or 'fall in voltage'.

2. In a domestic installation it is usually the electrical worker's responsibility to ensure that the voltage drop is within the limits imposed by the Wiring Rules.

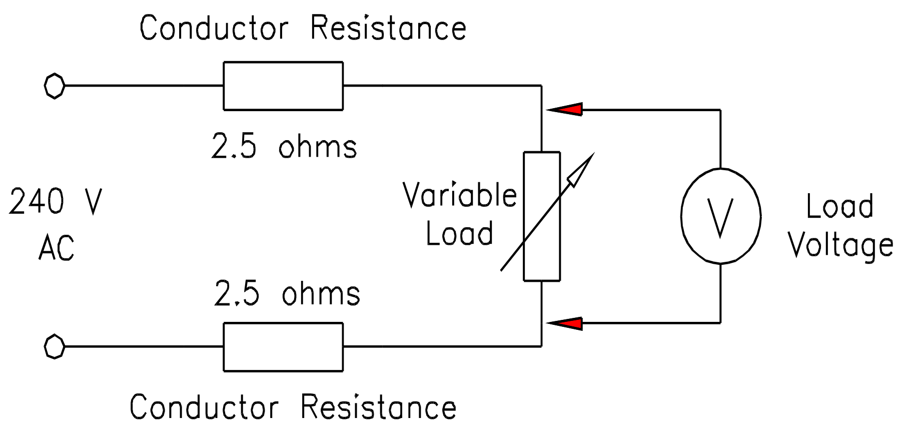
Principles

3. Voltage drop can only occur in a circuit when current is flowing. So, using Ohm's Law:

Volt Drop = Current in a circuit x resistance of the circuit.

V = I x R

4. **Exercise** Calculate the volt drop in the circuit below if a constant voltage of 240 volts a.c. is applied and the load is varied to allow 1, 5, 10 and 20 amps to flow respectively. Note that it is a series circuit, so the voltage across each component is directly proportional to the resistance of the component.



5. **Solution**

Load of 1 A:
Vd = I.R
= 1 x 5
= 5 V

Voltage at the load = 240-5
= 235 V
=======

Load of 10 A:
Vd = I.R
= 10 x 5
= 50 V

Voltage at the load = 240-50
= 190 V
=======

Load of 5 A:
Vd = I.R
= 5 x 5
= 25 V

Voltage at the load = 240-25
= 215 V
=======

Load of 20 A:
Vd = I.R
= 20 x 5
= 100 V

Voltage at the load = 240-100
= 140 V
=======

6. You can see from the example above that as the current in the circuit is increased, the voltage drop increases - i.e. the voltage at the load falls from 240 volts on no load to 140 volts on the full load of 20 amps.

7. The voltage drop in a circuit can be reduced by reducing the resistance of the circuit or the current flowing in it (V = I.R).

Maximum Allowable Voltage Drop

8. Wiring Rules Clause 3.6.2 requires that the volt drop between the point of supply and any point of a 240 or 415 volt installation shall not exceed 5% of the nominal supply voltage. Since 5% of 240 is 12 volts, this means that the voltage measured at any point in the installation must never be less than 240-12 or 228 volts.

9. In a three phase circuit 5% of 415 V is 20.75 V, so the minimum permissible voltage at any point is 415-20.75 or 394.25 V.

10. Limiting the volt drop to 5% of the supply voltage ensures that:

    a. There is sufficient voltage to provide satisfactory operation of any equipment being supplied.

    b. Under short circuit conditions the cable impedances, including that part of the earthing conductor, are sufficiently low to operate the circuit protection device.

11. In an extra-low voltage circuit, the maximum allowable voltage drop is 10% - see AS/NZS 3000 Clause 7.5.7.

12. The circuit current for volt drop purposes is the steady state current and does not include high transient currents such as those which flow when a motor starts or a solenoid is energised.

13. Clause 3.6.2(c) of AS/NZS 3000 specifies that voltage drop for final subcircuits with distributed loads (such as socket-outlets and lighting) may be calculated using 50% of the current rating of the protective device.

Reducing Voltage Drop

14. The voltage drop in a circuit can be reduced by reducing the resistance of the circuit or the current flowing in it. This can be done by:

    a. Increasing the cable size or connecting additional cables in parallel. Note that the Wiring Rules places restrictions on connecting cables in parallel, mainly that cables must be at least 4 mm^2 and they must be made of the same material and same cross sectional area - see AS/NZS 3000 Clause 3.4.3.

    b. Reducing the current flowing in the circuit by reducing the load (this is not usually practical).

    c. Reducing the length of the cable run (this is not usually practical).

Determining Minimum Cable Size

15. AS/NZS 3008.1.1 Section 4 and AS/NZS3000 C8 provide information on how to determine the minimum permissible size of cable for a specific run without exceeding the maximum permissible voltage drop. AS/NZS 3008.1.1 provides a detailed treatment using several different methods. The mV/A.m method of determining voltage drop in AS/NZS 3008.1.1 (Clause 4.2) is the only method required for this module. The same basic process can be applied to consumer mains, sub-mains or final sub-circuits.

16. The calculations in AS/NZS 3008.1.1 (Clause 4.2) are based on a special unit called Vc which is the voltage drop in millivolts per ampere metre (mV/Am). Values of Vc are given for three phase circuits in Tables 40 to 50. The value of Vc for a specific circuit is found using the equation:

$$V_C = \frac{1000 \quad V_d}{L \times I}$$

Note: To convert single phase voltage drop (mV/A.m) values to three phase values, multiply the single phase value by 0.866. To convert three phase Vc values to single phase values, multiply the three phase values by 1.155 (See AS/NZS 3008.1.1 Clause 4.2 Note)

Where:

Vc = the voltage drop over the route length of the circuit in millivolts per ampere metre (mV/A.m).
Vd = the actual voltage drop, in volts.
L = the route length of the circuit, in metres. The route length is the length of the RUN (i.e. if the circuit was in conduit it is the length of conduit).
I = the maximum demand current in the cable in amps.

17. In general, selecting a suitable cable for a given circuit involves calculating the value of Vc, then looking up the appropriate tables and selecting a cable which has a value of Vc which is equal to or less than the calculated value. It is usually useful to draw a simple line diagram of the circuit and insert the known values before you begin a calculation.

18. **Example 1** A single phase circuit is to be buried direct in the ground and protected by a circuit breaker. If the route length of this circuit is 30 metres and the maximum demand is 10 amps, what is the smallest V75 TPS cable which could be used?

19. **Solution**

Given: Vc = ?
Vd = 12 V (i.e. 5% of 240 V)
L = 30 metres
I = 10 amps
L = 30 metres

$$V_C \quad = \quad \frac{1000 \quad V_d}{L \ \times I}$$

$$V_C \quad = \quad \frac{1000 \ x \ 12}{30 \ \times 10}$$

Vc = 40 mV/A.m

20. In this example the smallest permissible cable is one which will have a Vc equal to, or nearest to but less than, 40 mV/A.m. From AS/NZS 3008.1.1 Table 42, 1.5 mm^2 cable has a three phase Vc of 28.6 mV/A.m. at the maximum permissible operating temperature of the cable. The circuit in this example is single phase so this single phase Vc has to be converted to a three phase Vc by multiplying it by 0.866. So Vc = 40 x 0.866 = 34.64 mV/Am. Since this is the cable which has a Vc nearest to but less than 34.64 mV/A.m, it would be suitable.

21. 1.5 mm^2 cable is within the allowable limits for voltage drop, but the current carrying capacity for the given installation conditions must be checked to ensure that it is adequate. From AS/NZS 3008.1.1 Table 10 Column 23, 1.5 mm^2 cable has a current carrying capacity of 21 A. This is greater than the maximum demand of this circuit (10 A), so the cable is acceptable.

Calculations Involving Vc

22. AS/NZS 3008.1.1 provides tables of the current carrying capacity and Vc for various sizes of cables. If the Vc, length and maximum demand current are known the basic equation can be transposed to calculate the actual voltage drop for a given circuit. Similarly, other values such as length and demand current can be calculated if the other appropriate values are known. The relevant equations are given below, but you should make sure that you can perform the transposition yourself.

$$Vc = \frac{1000\ Vd}{L \times I} \qquad Vd = \frac{Vc \times L \times I}{1000} \qquad L = \frac{1000\ Vd}{Vc \times I} \qquad I = \frac{1000\ Vd}{Vc \times L}$$

23. **Example 2** It is proposed to use 2.5 mm^2 V75 TPS copper cable to supply a demand of 15 amps to a 240 volt load which is located 30 metres from the associated switchboard. Calculate the actual voltage drop and the voltage which would be measured at the load terminals.

24. **Solution** The three phase value of Vc for 2.5 mm^2 cable from Table 42 is 15.6 mA/A.m. To convert a three phase Vc a single phase value, multiply the three phase value by 1.155, so the equivalent single phase value is 15.6 x 1.155 = 18.02 mV/A.m., so the actual voltage drop can be calculated as follows:

$$Vd = \frac{Vc \times L \times I}{1000}$$

$$Vd = \frac{18.02 \times 30 \times 15}{1000}$$

$$= 8.1 \text{ volts}$$

25. So the voltage drop is 8.1 volts for this circuit and the voltage that would be measured at the load terminals would be 240 - 8.1 which is 231.9 volts.

26. **Example 3** A 240 volt 12 amp load is to be supplied by 2.5 mm^2 copper V75 twin and earth TPS cable installed enclosed in air. Determine the maximum permissible route length for the final sub-circuit if the voltage drop is not to exceed 3%.

27. **Solution** The single phase value of Vc for 2.5 mm^2 cable at its maximum operating temperature using Table 42 is 18 mV/A.m (15.6 x 1.155). The maximum route length for a 3% volt drop can be calculated as follows:

3% of 240 volts is 7.2 volts (240 x 0.03)

$$L = \frac{1000\ Vd}{Vc \times I}$$

$$= \frac{1000 \times 7.2}{18 \times 12}$$

$$= 33.3 \text{ metres}$$

28. **Example 4** A 15 amp load single phase load is to be supplied by 4 mm^2 copper V75 twin and earth TPS cable installed enclosed in air for a route length of 45 metres. The circuit protection device is a circuit breaker. Determine the maximum additional current this circuit could carry without exceeding the maximum allowable voltage drop.

29. **Solution** The single phase value of Vc for 4 mm^2 cable using Table 42 is 11.2 mV/A.m (9.71 x 1.155 mV/A.m). The maximum allowable current for a 5% volt drop can be calculated as follows:

5% of 240 volts is 12 volts (the maximum allowable volt drop)

$$I = \frac{1000\ Vd}{Vc \times L}$$

$$\frac{1000 \times 12}{11.2 \times 45}$$

$$\underline{\underline{23.8 \text{ amps}}}$$

30. The circuit can carry up to 23.8 amps without exceeding the maximum allowable voltage drop of 5% of the supply voltage. The original current was 15 amps, so the additional current is 23.8 - 15 which is 8.8 amps.

31. In the previous example the maximum current of 23.8 amps is less than the 30 amps given in Column 11 of Table 10 so it would be permissible. However, it is important to note that the permissible cable size depends on the maximum permissible current AND the maximum permissible voltage drop - not on either factor alone.

Calculating Overall Voltage Drop

32. In some cases it is necessary to calculate the total voltage drop in an entire installation which includes consumer's mains, sub-mains and a final sub-circuit. Under these conditions it is necessary to determine the voltage drop in each component of the circuit.

33. **Example 5** A 15 amp 240 volt single phase load is to be supplied by 1.5 mm^2 copper V75 twin and earth TPS cable installed unenclosed in air for a route length of 15 metres. Details of the mains and sub-mains are shown below. Each circuit protection device is a circuit breaker. What is the calculated voltage drop in the entire circuit? Is it permissible? What could you do if the voltage drop was too high?

```
|  Consumer Mains         Sub Mains        Final Sub-circuit
|                   -----                   ----             ------
*-/-----------------| MSB |-/------------------| DB |-/----------| LOAD |
| 240 V             -----                   ----             -----
|
      70 A                 40 A              15 A
      16 sq mm           6 sq mm           1.5 sq mm
      10 metres          25 metres         15 metres
```

34. **Solution** The value of Vc for each cable can be determined using Table 42 of AS/NZS 3008.1.1 and applying the relevant conversion factor, so the maximum voltage drop at each stage can be calculated as follows :

Consumer's Mains (16 mm^2 cable. Vc = 2.43 x 1.155 = 2.806 mV/A.m)

$$V_d = \frac{V_c \times L \times I}{1000} \qquad V_d = \frac{2.806 \times 10 \times 70}{1000} = 1.964\ V$$

Sub-mains (6 mm^2 cable. Vc = 6.49 x 1.155 = 7.496 mV/A.m)

$$V_d = \frac{V_c \times L \times I}{1000} \qquad V_d = \frac{7.496 \times 25 \times 40}{1000} = 7.496\ V$$

Final subcircuit (1.5 mm^2 cable. Vc = 28.6 x 1.155 = 33.033 mV/A.m)

$$V_d = \frac{V_c \times L \times I}{1000} \qquad V_d = \frac{33 \times 15 \times 15}{1000} = 7.425\ V$$

Total Voltage Drop = 16.885 volts

----

35. The total calculated voltage drop in the installation is above the maximum permissible value of 12 volts, therefore it is not permissible. The most practical way to reduce the volt drop is to increase the size of cable in one of the circuits. Increasing the size of the cable in the final sub-circuit to 4 mm^2 would reduce the volt drop in the sub-circuit, thus reducing the overall volt drop to a permissible value.

Three Phase to Single Phase

36. When a single phase circuit is taken from a three phase distribution board, the commencing single phase voltage for that circuit is calculated by dividing the three phase voltage by √3.

37. In the example below, the voltage drop in the consumer's mains is 4 volts, giving 411 volts at the main switchboard. Therefore the commencing single phase voltage at the MSB is 411/√3 or 237 volts. The same applies when a single phase circuit is taken from the three phase supply at a distribution board instead of the main switchboard.

```
|  Consumer's Mains         Sub Mains        Final Sub-circuit
|       Vd = 4 V     -----                ----               ------
*-///---------------| MSB |-/----------| DB |-/----------| LOAD |
| 415 V             -----                ----               -----
|                  411 V (3 phase)
                   237 V (1 phase (411/√3))
```

38. Tables 40 to 50 in AS/NZS 3008.1.1 give the values of Vc for balanced three phase circuits in which the route length and load current are known. The conductor temperature in the tables is the maximum temperature rating of the cables, as specified by the manufacturer. To obtain the single phase voltage drop from the three phase values of Vc given in tables 40 to 50, multiply the three phase voltage drop by 1.155 (see notes under Tables 3 to 21 in AS/NZS 3008.1.1.

Alternative Method

39. AS/NZS3000 shows an alternative method of calculating voltage drop in Table C7.

40. Clause C4.2, example 1 is used to find the minimum cable size for a specific *Voltage Drop %*. Care must be taken as with this method the cable selected must have an Am per %Vd of <u>not less than</u> the calculated amount.

41. Clause C4.2 example 2 is used to find the actual voltage drop in a specific cable. Care must be taken to remember that this method calculates the % volt drop in the cable. To find the actual volt drop, this figure must be changed to actual volt drop by multiplying the nominal voltage by %Vd/100.

For example: A 230 volt circuit has an allowable volt drop of 2%. Calculate the actual volt drop.

Vd = 230 X 2 / 100

Vd = 4.6 volts

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Voltage Drop in Cables

1. Calculate the voltage drop in one 240 volt single phase circuit of 16 square mm twin TPS cable installed partially surrounded by bulk thermal insulation. The route length is 25 metres and the maximum demand is 50 amps. Show all working.

2. Which table in AS 3008.1.1 gives the values of voltage drop in mV/A.m (Vc) for overhead (aerial) cables?

3. What is the lowest permissible voltage at any given appliance in a three phase 415 volt factory installation? Give the AS/NZS 3000 Clause number.

4. What is the lowest permissible voltage at any given appliance in a single 240 volt single domestic installation? Give the AS/NZS 3000 Clause number.

5. Determine the maximum permissible route length for a 2.5 square mm single phase 240 V hot water system final sub-circuit which is protected by a 16 A Type C circuit breaker. The voltage drop must not exceed 6 volts. Show all working. Give the AS/NZS 3008 or AS/NZS 3000 Clause or Table number.

6. What is the minimum permissible size of cable for a 240 volt single phase DOMESTIC lighting final sub-circuit which has a route length of 30 metres and is protected by a 6 A Type C circuit breaker? Allow a 3% volt drop. Give the AS/NZS 3000 Clause number.

7. Calculate the voltage at the end of an underground final sub-circuit if the installation is as follows: (Show all working.)

Consumer's Mains:
Three phase, 415 V, 20 metres, 70 A, 25 sq mm cable.

Sub-mains:
Three phase, 415 V, 10 metres, 40 amp, 16 sq mm cable.

Single Purpose Final sub-circuit:
Single phase, 240 V, 15 metres, 10 amp, 4 sq mm cable.

8. Calculate the voltage at the end of a 415 volt factory final sub-circuit if the installation is as follows: (Show all working.)

Consumer's Mains:
Three phase, Voltage drop = 4 volts.

Sub-mains:
Three phase, Voltage drop = 3 volts.

Distributed Load Final sub-circuit –protected by 16 Amp circuit-breaker:
Single phase, 240 V, 25 metres, 2.5 sq mm cable.

9. Determine the cable size required for a three phase 415 volt consumer's main which has a length of 35 metres. It is run underground in conduit and has a maximum demand of 40 amps per phase. Allow a maximum voltage drop of 8 volts. Show all working.

10. What special condition applies in relation to the voltage drop in final subcircuits which have a distributed load?

11. Calculate the voltage at the LOAD in the following 240 volt installation: (Show all working.)

```
 |  Consumer's Mains        Sub Mains        Final Sub-circuit
 |                  -----                 ----            ------
*-/-----------------| MSB |-/-----------------| DB |-/----------| LOAD |
 |                  -----                 ----            -----
 |   1 Phase              1 Phase              1 Phase
 |   16 mm^2              10 mm^2              6 mm^2
 |   25 metres            39 metres            15 metres
 |   70 amps              32 amps              25 amps
```

12. Calculate the voltage at the LOAD in the following 415 volt installation: (Show all working.)

```
 |  Consumer's Mains        Sub Mains        Final Sub-circuit
 |                  -----                 ----            ------
*-///---------------| MSB |-///-----------------| DB |-/----------| LOAD |
 |                  -----                 ----            -----
 |   3 Phase              3 Phase              1 Phase
 |   25 mm^2              16 mm^2              4 mm^2
 |   20 metres            30 metres            15 metres
 |   80 amps              32 amps              20 amps
```

13. Calculate the voltage at the LOAD in the following 415 volt installation: (Show all working.)

```
|  Consumer's Mains        Sub Mains        Final Sub-circuit
|                    -----                      ----          ------
*-///---------------| MSB |-/---------------------| DB |-/----------| LOAD |
|                    -----                      ----          -----
```

Consumer's Mains	Sub Mains	Final Sub-circuit
3 Phase	1 Phase	1 Phase
25 mm^2	10 mm^2	4 mm^2
25 metres	25 metres	15 metres
80 amps	32 amps	20 amps

14. What are the two MAIN factors which effect the voltage drop in a particular installation?

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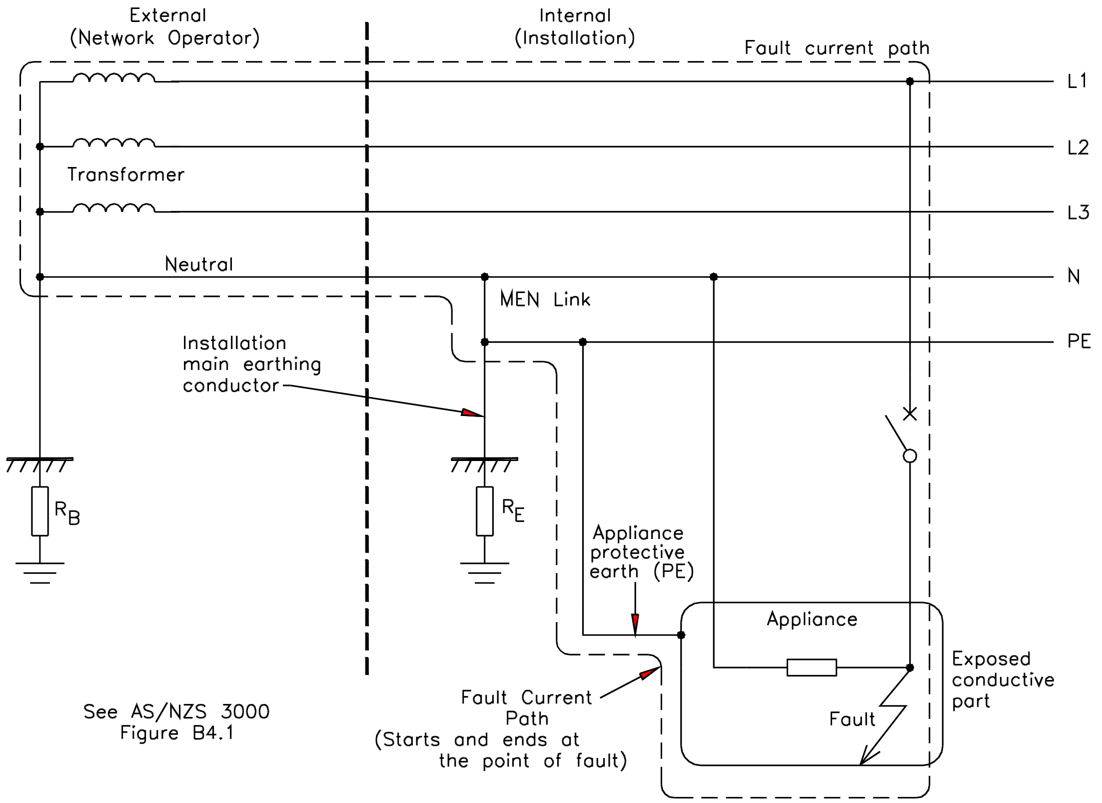
Cable selection based on fault loop impedance requirements

1. **Fault loop impedance**

Earth Fault-loop impedance is the impedance of the conductors in the series path taken by the current in the event of a fault between an active conductor and an earth conductor, starting and ending at the point of the earth fault.



2. A wide range of information on the requirements of fault loop impedance is provided in AS/NZS3000 Appendix B.
The purpose of planning and testing fault loop impedance is to ensure that the impedance of the fault path is low enough to allow the operation of the circuit protection device. Clause 1.5.5.3(d) states that when fault current is flowing, the protection device needs to automatically disconnect the supply within 0.4 seconds for socket outlets, hand-held or portable equipment and 5 seconds for other circuits.

3. To ensure operation of the circuit protection device within the proscribed time, the fault loop impedance must be low enough to allow a current flow of at least;

4	times the rated current of a type B circuit-breaker
7.5	times the rated current of a type C circuit-breaker
12.5	times the rated current of a type D circuit-breaker

Zs = Uo/Ia

Where: Z = earth fault-loop impedance
Uo = nominal phase voltage (230 volts)
Ia = the amount of current causing automatic disconnection of the supply within the proscribed time.

More information on calculating earth fault-loop impedance can be found in AS/NZS3000 – clause B4.5

4. **Calculations of circuit length, fault loop impedance and voltage drop**

AS/NZS3000 – clause B5.2 provides information on how to calculate the impedance of the internal component of the fault loop. It states that you can assume that there will be always be 80% (0.8) or more of the supply phase voltage (Uo) available at the protective device. The following formula can be used to calculate the maximum route length of a circuit to meet earth fault loop requirements.

$$Lmax = \frac{0.8 \quad Uo \quad Sph \quad Spe}{Ia \quad \rho \quad (Sph + Spe)}$$

Where:			
	Lmax	=	maximum route of circuit in metres
	Uo	=	nominal phase voltage (230V)
	ρ	=	resistivity of conductor in Ω-mm²/m
		=	22.5×10^{-3} for copper
		=	36×10^{-3} for aluminium
	Ia	=	trip current setting for the instantaneous operation of a circuit breaker
	Sph	=	cross sectional area of the active conductor (mm^2)
	Spe	=	cross sectional area of the protective earthing conductor (mm^2)

5. Using the information from AS/NZS3000 – Table B1, the maximum route length of a single phase 230 volt circuit, wired with 1.0 mm^2 twin and earth TPS cable, protected by 10A type 'C' MCB is 55 metres.

6. Calculating the volt-drop of the same circuit supplying a 10 amp load.

$$V_d = \frac{L \quad I \quad V_c \quad 1.155}{1000}$$

$$V_d = \frac{55 \quad 10 \quad 44.7 \quad 1.155}{1000}$$

$$V_d = 28.4\ volts$$

A voltage drop of 28.4 volts far exceeds the 5 % maximum voltage drop allowed by the Wiring Rules. This circuit would require a larger cable size to limit the volt-drop to an acceptable level. In most cases, if the selected cable meets the volt-drop requirements of the circuit, the earth fault loop requirements should be met. Verification of earth fault loop impedance testing should always be carried out to ensure compliance with the Wiring Rules.

7. **Exercise**
To examine the relationship between the requirements of earth fault loop impedance and voltage drop. Use AS/NZS 3000 Table B1 to determine maximum route length and AS/NZS3008.1.1 Table 42 to calculate voltage drop.

Complete the Table

Conductor size (mm^2)		Rating of Circuit breaker (Amperes)	Circuit breaker Type	Max length for fault loop impedance Table B1	Voltage drop incurred over this length		Is this volt-drop acceptable? Yes/No
Active	Earth				Three phase	Single phase	
1.5	1.5	10	C				
2.5	2.5	20	C				
6.0	2.5	40	C				
10.0	4.0	50	C				
16.0	6.0	80	D				
50.0	16.0	125	D				

Hint: Work out the voltage drop for a three phase circuit first, using the maximum length from Table B1, then multiply your three phase volt-drop by 1.155 to obtain your single phase answer.

Cable Selection - Co-ordination of current carrying capacity, voltage drop and fault-loop impedance

8. Up to now we have only considered current carrying capacity and volt-drop when selecting a cable to supply an electrical load. The follow exercise is to make you aware that in certain cases, fault loop impedance must also be taken into account to ensure that protective devices will protect the circuit under fault conditions.

Exercise
A three phase load of 60A is to be supplied by conductors enclosed in a conduit installed underground. The route length is 80 metres and the volt drop must not exceed 15 volts. The circuit is protected by a 63A type 'D' circuit breaker.
Using AS/NZS 3008.1.1, determine the Active conductor size. _______ mm^2
Using AS/NZS 3000 Table 5.1 determine the minimum size of the earth conductor ____________mm^2

Using AS/NZS 3000 Table B.1, check that this installation complies with earth fault loop requirements. Does it comply? Yes/No.

If the installation does not comply, your options are to either increase the size of the earthing conductor or increase the size of the Active conductors. Calculate both options to determine the most economical method to comply with voltage drop and fault loop impedance requirements.

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Cable selection based on fault loop impedance requirements

1. Calculate the maximum route length for fault loop impedance of a single phase circuit protected by 10A type ‘C’ MCB and wired in 2.5 mm^2 TPS twin and earth.

2. A 400 volt mine conveyor belt drive motor has a calculated three phase maximum demand of 32A. The route length of the circuit is 48 metres. The installation condition for this circuit is enclosed underground. Maximum voltage drop allowed for circuit is 6 volts. The main switchboard at the origin of the circuit will have 80 Amp HRC fuses to provide short-circuit protection.

   Determine:

   A. Conductor sizes to meet requirements of current carrying capacity, voltage drop and earth fault loop impedance.

   B. What are the options to provide overload protection for the motor?

   C. A method of providing effective earthing of the motor that meet the requirements of earth fault loop impedance.

   Note: To calculate Earth fault loop impedance using the formula

$$Lmax = \frac{0.8 \quad Uo \quad Sph \quad Spe}{Ia \quad \rho \quad (Sph + Spe)}$$

   You will need to calculate $Ia = \frac{U_o}{Z_s}$ Where U_O = 230 Volts and Z_s (80Amps) can be found in Table 8.1.

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Cable Selection for Final Subcircuits

1. A final sub-circuit is a circuit which originates at a switchboard, to which only consuming devices or points are to be connected (See AS/NZS 3000 Clause 1.4.115).

2. Clause 1.6.5 of AS/NZS 3000 specifies that the installation shall be divided into circuits as necessary to avoid danger, minimise inconvenience in the event of a fault, and facilitate safe operation, inspection, testing and maintenance.

3. The most common types of final subcircuits are:

   a. Lighting circuits - Circuits which consist solely of lighting points.
   b. Power circuits - Circuits which consist solely of socket outlets.
   c. Mixed circuits - Circuits which consist of a combination of points such as lighting points, socket outlets, and permanently connected fixed appliances.
   d. Circuits for permanently connected fixed equipment.

4. Table 6.1 in AS/NZS 3018 and Table C9 in AS/NZS 3000 provide guidance on the number of points per final subcircuits in domestic installations.

5. In general the maximum demand of a final sub-circuit is deemed to be the full connected load. In practice the maximum demand of a final sub-circuit is usually limited by the current rating of the circuit protection device, which should not exceed the current carrying capacity of the circuit conductor.

6. The type and number of points to be installed on a particular final sub-circuit is usually given in the specifications for the installation, but in the case of small domestic installations it is often left to the electrician to decide.

7. The process of planning for final subcircuits typically involves the following steps:

   a. Determine how many circuits will be required, and their type.

   b. Determine the type and rating of the circuit protection device(s) to be used. Refer to Table B.1 in AS/NZS 3000 for the maximum length of cable allowable for a given circuit protection device. Note that Type C circuit breakers are usually used for general purpose applications and Type D can be used for motor starting. The lengths in Table B.1 are based on 230 volts; they must be multiplied by 1.04 for 240 volt circuits.

   c. Determine how many points there will be on each circuit (see AS/NZS 3000 Clause 1.6.5 and table C9). A general rule is to limit the number of lighting points in a domestic installation to 20 points per circuit and have a maximum of 16 points on a power circuit.

   d. Determine the most appropriate type of cable or wiring system for the installation having regard for the installation conditions.

   e. Determine the minimum size of cable required for each circuit. (see AS/NZS 3008.1.1).

   f. Checking to see that the voltage drop of the selected cable is permissible (see values of Vc in AS/NZS 3008.1.1 and/or AS/NZS 3000 Table C8)

8. Selection of cables for circuits requires the use of AS/NZS 3008.1.1; it is very important to read all footnotes and specified references.

9. Chapter 5 of Electrical Wiring Practice (7th ed.), Volume 2, by Pethebridge and Neeson provides a comprehensive coverage of the use of Standard AS/NZS 3008.1.1.

10. Appendix A of AS/NZS 3008.1.1 gives several examples of methods of selecting cables to satisfy current carrying capacity, voltage drop and short circuit performance.

Fault Loop Impedance

11. Clause 1.5.5.3c of the Wiring Rules requires that if a fault of negligible impedance occurs anywhere in an electrical installation between an active conductor and a protective earthing conductor or exposed conductive part, automatic disconnection of the supply will occur within the specified time. In general the disconnection times are 0.4 seconds for most final subcircuits that supply socket outlets and 5 seconds for other circuits supplying fixed equipment (see Clause 1.5.5.3d).

12. The impedance of the fault current path is known as the 'fault loop impedance' and is shown in Clause B4.4 of the Wiring Rules.

13. Table B1 in the Wiring Rules gives the maximum circuit lengths for different sizes of conductors and protective devices using approximate mean tripping currents.

Installation Conditions

14. The installation conditions are a significant factor in the selection of cables because they affect the rate at which heat can be dissipated by the cables. Conditions under which the heat cannot be removed easily, or where cables are grouped so that mutual heating occurs require a reduction of the current carrying capacity (de-rating).

15. AS/NZS 3008.1.1 Clause 3.4 describes installation conditions under the following main headings:

    a. Cables installed in air.
    b. Cables installed in thermal insulation.
    c. Cables buried direct in the ground.
    d. Cables installed in underground wiring enclosures.

External Influences

16. AS/NZS 3008.1.1 - Clause 3.5 describes the following external influences that have an effect on cable selection, and require the use of de-rating factors:

    a. Grouping of cables.
    b. Ambient temperature
    c. Depth of laying.
    d. Thermal resistivity of soil
    e. Varying loads.
    f. Thermal insulation.
    g. Direct sunlight.

17. Read the following sections in AS/NZS 3000:2018 - Wiring Rules

    Clause 1.5 Fundamental principles
    Clause 3.6 Voltage drop
    Appendix B Circuit protection guide

18. Read the following section in Chapter 5 of Pethebridge and Neeson Volume 2:

    Section 5.3 Factors affecting cable selection. Pages 119 - 132

19. Read the following section in AS/NZS 3008.1.1 - Electrical installations. Selection of cables:

    Clause 3.4 Installation conditions
    Clause 3.5 External influences on cables

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Cable Selection for Final Subcircuits

1. What is the maximum demand of a single purpose lighting final sub-circuit in a domestic installation if it is wired in 1 mm^2 twin and earth TPS installed clipped to ceiling joists in the roof space? The circuit is protected by a 6 amp miniature circuit breaker.

2. What type of over current protection device would be most suitable for each of two 1 mm^2 TPS lighting circuits in a domestic installation, if the possible options are circuit breaker or HRC fuse? Why?

3. What is the maximum demand of a single purpose final sub-circuit supplying a 9 kW 240 V single phase fixed electric cooking range in a domestic installation? What is the minimum permissible size of V90 TPS copper cable in flexible conduit?

4. A single purpose final sub-circuit for a 14 amp 240 volt fixed reverse cycle air conditioner is to be installed in a domestic installation using 15 metres of twin and earth TPS in the cavity and clipped to the side of ceiling joists in the roof space? The circuit is to be protected by 16 amp miniature circuit breaker. What is the 'installation condition' for this arrangement.

5. What is the minimum permissible size of cable for Question 4 above?

6. What is the minimum permissible size of cable for Question 4 above if the air conditioner was located 30 metres from the associated switchboard and it was a non-domestic installation with bulk thermal insulation on the ceiling?

7. Four double 240 volt 10 amp socket outlets and two 60 watt incandescent lights are to be installed on a new TPS mixed circuit in a garage in a single domestic installation. The garage is attached to the house and the wiring is through the roof space, clipped to the side of the ceiling joists. Two single purpose power circuits already exist in the house. Determine the following:

   a. The type and rating of the circuit protection device(s).
   b. The installation conditions.
   c. The minimum permissible size of cable.
   d. The minimum permissible size of earthing conductor.

   Draw a neat wiring diagram showing how the circuit would be connected. Make valid assumptions for any detail not given.

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Motor Installation Work Sheet

A standard three terminal delta connected 415 volt 3 kW (6.5 amp) three phase motor is to be installed to drive a ground level water irrigation pump in a commercial market garden which includes a domestic dwelling.

The motor is located in a pump shed 30 metres from the main switchboard in the dwelling, and the wiring to the motor is to be a single purpose TPI final sub-circuit run underground in rigid PVC conduit in sandy soil with no obstructions.

The motor is to be controlled by a direct on line (DOL) magnetic starter located near the motor in the pump shed, with a local stop-start station on the pre-wired starter. The starter has a 415 volt coil and a thermal overload which can be set to any value between 5 and 10 amps.

Circuit protection is to be installed on the main switchboard.

Answer the following questions for this installation, and give the AS/NZS 3000 reference where applicable. Make valid assumptions for any detail not provided.

1. How many cables need to be run from the main switchboard to the motor starter? What colours would they be?

   ____

2. What type of circuit protection would you select for this installation?

   ____

3. What is the current rating of the circuit protection device?

   ____

4. What is the minimum permissible size of cable for the three actives from the switchboard to the motor starter?

   ____

5. What is the minimum permissible size of cable for the three actives from the starter to the motor?

   ____

6. What is the minimum permissible size of the earthing conductor for the motor?

   ____

7. What size rigid PVC conduit would be required from the dwelling to the pump shed?

   ____

8. What voltage would there be at the motor when the motor was running on full load?

   ____

9. What is the maximum current rating of the cables under the given installation conditions?

10. What additional electrical equipment would be required in the pump shed, other than the motor, the starter and the wiring accessories?
Give the relevant details.

11. To what point on the main switchboard should the circuit earthing conductor be connected?

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Maximum Demand in Multiple Installations

Calculate the maximum demand and cable sizes for consumer mains and sub-mains for each unit in the following multiple installation, considering the installation conditions and volt drop requirements. Refer to the attached Site Plan - Home Units. Make valid assumptions for details not provided.

The electrical installation is a group of 8 home units consists of the following individual loads:

Units	Connected Load
1, 3 & 5	24 x lighting points 8 x single 10 A socket outlets 20 x double10 A socket outlets 2.4 kW HWS 8 kW cooking range
2, 6 & 7	26 x lighting points 12 x single 10 A socket outlets 18 x double10 A socket outlets 2.4 kW HWS 9.6 kW cooking range
4 and 8	33 x lighting points 14 x single 10 A socket outlets 16 x double10 A socket outlets 2.4 kW HWS 7.8 kW cooking range

Notes:

a. All hot water systems are electric storage type.

b. Sub-mains to units 1, 2 and 3 are laid flat and touching in one side of the trench. Sub-mains to units 4, 5, 6 and 7 are laid touching in the other side of the trench. No de-rating is required between the two groups.

c. Sub-mains to unit 8 are through the wall cavity behind the main switchboard.

d. Specify appropriate earthing arrangements for the units.

e. Specify a nominal volt drop for each unit.

Questions

1. What is the maximum demand of the entire installation?

2. What size consumer mains will be required if they are 4 core circular TPS copper cable laid 500 mm underground in PVC heavy duty conduit having a length of 26 metres and protected by HRC fuses?

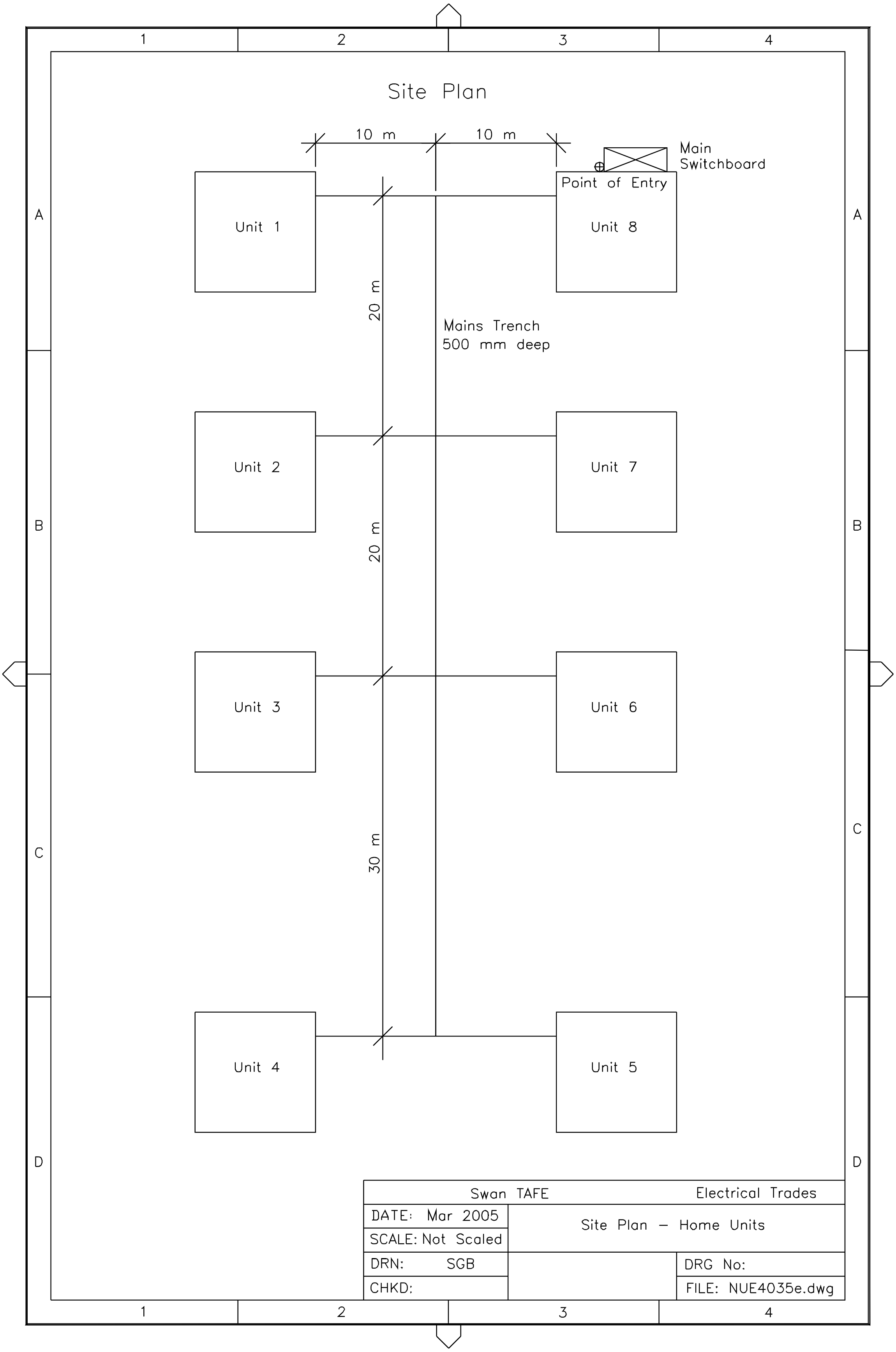
3. What size main earthing conductor would be required to run to the main earthing electrode?

4. What minimum size sub-mains are required for each unit if they are V90 TPI copper cables in underground conduit, allowing for volt drop?

5. What size earthing conductor would be required at each unit?

6. Use the site plan to determine the minimum planning length of all cables.

Site Plan -Home Units



Maximum Demand Calculation Table (Single or Three Phase)

Load Group	Load	Remarks	Calculations	Contribution per phase (amps)		
				R	W	B

Answer Sheet for Installation Design for Unit 6:

Item	**Answer**
Minimum current carrying capacity consumer's mains in WA according to WAER	
Maximum demand consumer's mains.	
Minimum size conductor consumer's mains, based on current carrying capacity	
Minimum size conductor consumer's mains, based on volt-drop	
Size of cable selected for consumer's mains	
Actual volt-drop of consumer's mains	
Minimum size conductor main earth	
Minimum size cable for selected final sub-circuit, based on current carrying capacity	
Minimum size cable for selected final sub-circuit, based on volt-drop	
Size of cable for the selected final sub-circuit	
Actual volt-drop of selected final sub-circuit	
Maximum fault loop impedance of the final sub-circuit.	
Size type-C circuit breaker of the final sub-circuit, based on AS/NZS 3000 clause 2.5.3.1	

Notes

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 6 Introduction	G107A SGB 08/2014

Methods and Devices for Providing Protection

Task:

To select methods and devices for protecting person and livestock against the dangers that may arise from contact with exposed conductive parts which may become live under fault conditions for a given installation.

Why:

All electrical circuits and protection devices must be designed to operate safely under normal operating conditions and anticipated fault conditions.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set tasks.

3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice (7th ed.), Pethebridge, K. & Neeson, I.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* AS/NZS 4836.2011 - Safe working practice on low-voltage electrical installations
* WA Electrical Requirements:2014.
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 6 Study Guide	G107A SGB 08/2014

Methods and Devices for Providing Protection

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Clause 1.5 Fundamental principles
Appendix B Circuit arrangements

Electrical Wiring Practice (7th ed.) Volume 1

Chapter 3 Regulations and Standards
3.6 Fundamental Requirements

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.
3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.
4. Complete the projects in this manual.
5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

	Select wiring systems and cables for LV general electrical installations	Section 6 Summary	G107A SGB 08/2014

Methods and Devices for Providing Protection

Fault Protection (Indirect Contact)

1. Clause 1.5.5.1 of AS/NZS 3000 requires that persons and livestock shall be protected against dangers that may arise from contact with exposed conductive parts which may become live under fault conditions (indirect contact).

2. Indirect contact is defined as contact with a conductive part which is not normally live but has become live under fault conditions (due to insulation failure or some other cause). See AS/NZS 3000 Clause 1.4.39 and Figure 1.3.

3. Clause 1.5.5.2 of AS/NZS 3000 gives the principles of providing protection against indirect contact, i.e.

   a. Prevent fault current from passing through the body.
   b. Limit the fault current.
   c. Automatically disconnect the supply.

4. Clause 1.5.5.3 of AS/NZS 3000 gives the acceptable methods of providing protection against indirect contact, i.e.

   a. Automatic disconnection of the supply.
   b. Use of Class II (double insulated) equipment.
   c. Electrical separation.

5. Clause 1.5.5.3 of AS/NZS 3000 gives information relating to automatic disconnection of the supply, including touch voltage limits, fault loop impedance requirements maximum disconnection times for sub mains and final subcircuits.

6. Clause 1.5.6.3 of AS/NZS 3000 allows the use of RCDs as protection against indirect contact by providing automatic disconnection of supply.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 6 Worksheet	G107A SGB 08/2014

Methods and Devices for Providing Protection

1. What is meant by the term Fault protection (indirect contact) according to the Wiring Rules?

2. What are the three METHODS of providing protection for Fault Protection (indirect contact) according to the Wiring Rules?

3. What is the maximum touch voltage limit in a 240 volt a.c. circuit under earth fault conditions?

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 7 Introduction	G107A SGB 08/2014

Selection of Protective Devices

Task:

To select overload and short circuit protection devices in compliance with coordination requirements of Wiring Rules and load characteristics.

Why:

All protective devices must be able to operate safely under normal operating conditions and anticipated fault conditions. Protective devices must comply with appropriate equipment/device and installation standards.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set laboratory tasks.

3. You must achieve 100% in a final competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice (7th ed.), Pethebridge, K. & Neeson, I.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* WA Electrical Requirements:2014.
* AS/NZS 4836.2011 - Safe working practice on low-voltage electrical installations
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 7 Study Guide	G107A SGB 08/2014

Selection of Protective Devices

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Clause 1.5 Fundamental principles
Section 2 Circuit arrangement, control and protection
Appendix B Circuit protection guide

Electrical Wiring Practice (7th ed.) Volume 2

Chapter 1 Electrical Protection and Protective Devices.

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.
3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.
4. Complete the projects in this manual.
5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 7 Summary	G107A SGB 08/2014

Selection of Protective Devices

1. The selection of overload and short circuit protection devices must be based on several considerations, including:

    a. Current-carrying capacity.
    b. Prospective fault current.
    c. Fault loop impedance requirements.
    d. Impulse voltage (AC or DC).
    e. Operating time
    f. Installation conditions
    e. Any external influences under normal operating conditions.

2. In general, AS/NZS 3000 specifies the minimum requirements in terms of acceptable performance and least cost.

3. The main requirements relating to the selection of protective devices are contained in the Wiring Rules at Clauses 2.4 to 2.7.

4. Features of the requirements include:

    a. Protection against direct contact and indirect contact.
    b. Protection against overcurrent or excessive earth leakage.
    c. Protection against overvoltage and under-voltage.

5. This Section deals with:
    a. Coordination between conductors and protective devices.
    b. Possible injuries from short circuits.
    c. Selection of acceptable devices for protection from overloads and short circuits.

Coordination

6. Coordination between protective devices and circuit protection devices is necessary to ensure that cables/conductors are not subjected to stress from overloads or short circuits. Protective devices such as fuses and circuit breakers must therefore operate and isolate the circuit in which they are connected, before the maximum ratings of the cables or conductors are exceeded.

7. Clause 2.5.3.1 and Appendix B of the Wiring Rules details the coordination requirements for both fuses and circuit breakers with their associated connected circuit cables/conductors. Electrical Wiring Practice Volume 2 Chapter 1 page 17 contains typical time/current characteristic curves for circuit breakers.

Possible Injuries from Short Circuits.

8. Clause 1.4.39 of the Wiring Rules defines 'indirect contact' as contact with a conductive part which is not normally live but has become live under fault conditions. If this happens and an earthing conductor has not been installed, a person touching that conductive part is likely to receive an electric shock. Refer to Figure 1.3 in the Wiring Rules.

Selection of Acceptable Devices

9. The requirements for devices for protection against overcurrent are set out in Clause 2.5 of the Wiring Rules and in Chapter 1 of Electrical Wiring Practice Volume 2. Note that when enclosed fuse links (i.e. HRC fuses) are to be installed for protection of electric motor circuits, then special motor starting fuses must be provided.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 7 Worksheet 1	G107A SGB 08/2014

Selection of Protective Devices

1. Explain the purpose of protection of conductors against overcurrent.

2. Explain what is meant by the term 'coordination' between conductors and protective devices such as fuses and circuit breakers.

3. Why are circuit breakers used instead of fuses in many electrical installations?

4. Explain how a person can receive an electrical shock from the metallic frame of a single insulated electrical motor which has developed an earth fault.

5. List two common electrical devices which provide protection against overcurrent.

6. State the Wiring Rules Clause number that allows devices for protection against both overcurrent and fault current.

7. A 240 volt final sub-circuit supplies 10 amp socket outlets and is protected by a 16 amp Type C circuit breaker. Use AS/NZS 3000 to determine the maximum internal fault-loop impedance of the final sub-circuit if the supply is unavailable.

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Cable Selection Installation Project

3 x Factory/Warehouse Units

Objective

To determine the size and type of cables required for mains, sub-mains and final subcircuits in a given 400v non-domestic electrical installation.

Equipment

Electrical specifications relating to the installation.
Floor plan with electrical layout for the installation.
Manufacturers' catalogues as required.
AS/NZS 3000:2018 - Wiring Rules.
AS/NZS 3008.1.1:2017 - Cables for alternating voltages up to and including 0.6/1 kV.
5 mm square graph paper.

Procedure

1. Examine the specifications provided. Make valid assumptions for detail not given.

2. Determine the size, type and enclosure of all cables in the installation (including the earthing conductors) so that the installation complies with all statutory requirements. Show all calculations in a systematic manner so that they can be checked. Show all assumptions where applicable.

3. Determine the type and rating of all components (MCBs etc.) taking in to consideration the correct current carrying capacity and fault loop impedance. Show calculation of full load current for furthermost 10 A socket outlet in Unit 1. Check volt drop for furthermost 10 A socket outlet in Unit 1.

4. Determine the size and layout of the components on the distribution sub-switchboards. Draw a neat scaled diagram of one sub switchboard.

5. Determine the size and layout of the components on the main switchboard. Draw a neat scaled diagram of the main switchboard.

6. Submit your work to your Lecturer for comment and assessment.

Factory Installation Project

3 x Factory and Warehouse Units Specifications

1. Each unit is to be fed by a 3 phase underground sub-main originating from a self-standing weatherproof meter enclosure mounted on the front boundary. The enclosure is fed by a 3 phase mains cable running within a suitable steel consumers pole, the pole being situated as close as possible to the meter enclosure. The building has a concrete floor slab and concrete external/adjoining walls. The high roof is corrugated iron supported on steel trusses. The office and toilets are timber framed with Gyprock internal linings and ceilings. Valid assumptions need to be made for detail not provided. All working must be shown so that it can be checked by others.

Meter Enclosure

2. Special Requirements

   a. Enclosure to be constructed in such a manner as to comply with AS/NZS 3000 and local requirements.
   b. Enclosure to be galvanised and painted.
   c. To have glass ports installed.
   d. To be lockable by a supply authority key.

Units 1, 2, 3

3. Lighting - Office and Exterior

   Twin 36 W diffused fluorescent (0.5 amps each)
   Illuminated exit signs, self-charging (0.3 amps each)
   18 W exterior fluorescents (0.25 amps each)

   Power

   Double 10 amp single phase socket outlets
   Single 10 amp single phase socket outlet
   15 amp 3 phase HWS
   20 amp 3 phase socket outlets x 3

   Lighting

   250 W mercury vapour suspended luminaires
   60 W batten holders in toilets
   500 W exterior sodium vapour floodlights

Current calculation for discharge lighting (mercury vapour, sodium vapour metal halide, etc)

I = (P x 1.8) ÷ V

Eg The load current of a 400W sodium vapour luminaire is I = 400 x 1.8 ÷ 240
= 3 amps

Sample Maximum Demand Calculation Sheet (Single or Three Phase)

Maximum Demand Calculation Table (Single or Three Phase)

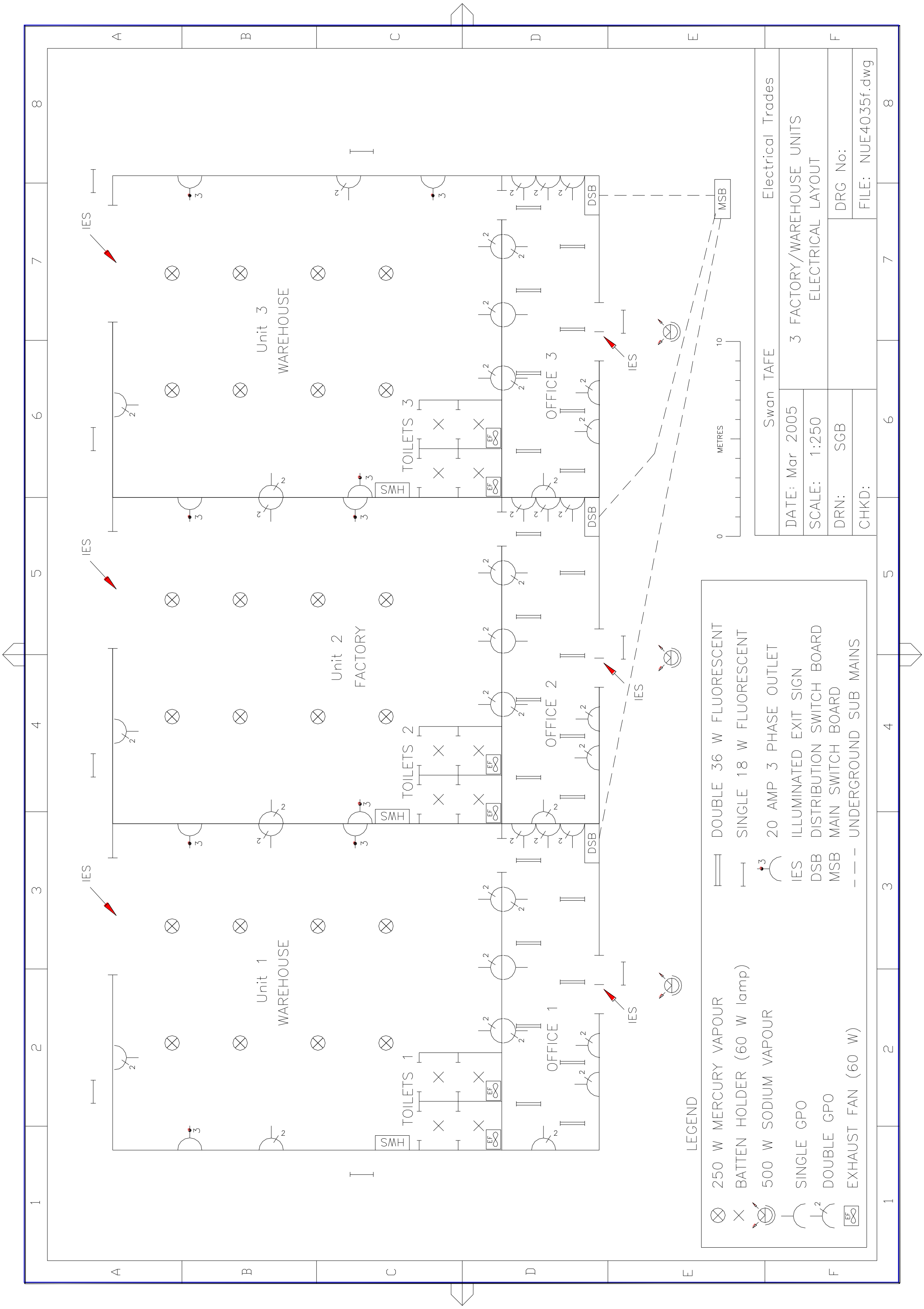
Load Group	Load	Remarks	Calculations	Contribution per phase (amps)		
				R	W	B

Answer Sheet for Installation Design:

Item	Answer
Minimum current carrying capacity consumer's mains in WA according to WAER	
Maximum demand consumer's mains.	
Minimum size conductor consumer's mains, based on current carrying capacity	
Minimum size conductor consumer's mains, based on volt-drop	
Size of cable selected for consumer's mains	
Actual volt-drop of consumer's mains	
Minimum size conductor main earth	
Minimum size cable for selected final sub-circuit, based on current carrying capacity	
Minimum size cable for selected final sub-circuit, based on volt-drop	
Size of cable for the selected final sub-circuit	
Actual volt-drop of selected final sub-circuit	
Maximum fault loop impedance of the final sub-circuit.	
Size type-C circuit breaker of the final sub-circuit, based on AS/NZS 3000 clause 2.5.3.1	

Use the three phase 20A socket outlet adjacent to the HWS as the selected final sub-circuit for the above information.

Floor Plan with General Electrical Layout



Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 8 Introduction	G107A SGB 08/2014

Selection of Devices for Isolation and Switching

Task:

To select devices for isolation and switching in an electrical installation in compliance with the Wiring Rules.

Why:

All protective devices must be able to operate safely under normal operating conditions and anticipated fault conditions. Protective devices must comply with appropriate equipment/device and installation standards.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice (7th ed.)- Volume 1, Pethebridge, K. & Neeson, I.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* WA Electrical Requirements:2014.
* AS/NZS 4836.2011 - Safe working practice on low-voltage electrical installations
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 8 Study Guide	G107A SGB 08/2014

Selection of Devices for Isolation and Switching

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Clause 1.5 Fundamental principles
Clause 2.3 Control of Electrical Installation

Electrical Wiring Practice (7th ed.) - Volume 1.

Section 5.3 General switching, lighting and socket-outlets
Switching classifications, devices and purposes – page 123
Current rating and utilisation of switches – page 124

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.
3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.
4. Complete the projects in this manual.
5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 8 Summary	G107A SGB 08/2014

Selection of Devices for Isolation and Switching

1. The selection of devices for isolation and switching must be based on several considerations, including:

    a. Current-carrying capacity.
    b. Prospective fault current.
    c. Likely impulse voltage (AC or DC).
    d. Installation conditions.
    e. Number of phases or conductors to be switched.
    f. Any external influences under normal operating conditions.

2. In general, AS/NZS 3000 specifies the minimum requirements for isolation and switching in terms of acceptable performance and least cost.

3. The wiring rules require every electrical installation to be provided with devices for isolation and switching to prevent or remove hazards associated with the installation and maintenance of equipment.

4. Clause 2.3.2 lists common requirements for isolation and switching devices to enable operation and maintenance to be carried out safely, including:

    a. An earthing or combined earthing/neutral conductor shall not be switched.
    b. A neutral conductor shall not be switched unless it is a multiple switch including a contact intended for connection to the neutral.

5. Special requirements apply for MAIN switches as required by Clause 2.3.3. These include ready access and clear identification.

6. Every sub-main and final sub-circuit exceeding 100A shall be controlled by a separate isolating switch – see AS/NZS 3000 Clause 2.3.4.2.

Protection Against Mechanical Movement

7. Where isolation of switching for motor circuits is required, the devices must comply with clause 4.13.1.1 of the Wiring Rules.

Other Switching Classifications, Devices and Purposes

8. Special consideration must be given to isolation and switching devices for:

   a. Those installations where shutting down is required for mechanical maintenance – see Clause 2.3.6.

   b. Emergency switching including emergency stopping – see Clause 2.3.5

   c. Functional switching or control switching – see Clause 2.3.7.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 8 Worksheet	G107A SGB 08/2014

Selection of Devices for Isolation and Switching

1. Why are devices for isolation and switching necessary?
2. List four classifications of devices for isolation and switching.
3. Under what conditions can a neutral conductor be switched?
4. Name the six separate parts of an electrical installation that the Wiring rules do NOT require to be controlled by a main isolating switch.
5. List the four requirements for the identification of main switches.
6. Why is emergency switching necessary? List six examples of situations where means for emergency switching is provided.

Notes

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 9 Introduction	G107A SGB 08/2014

Design and Layout of Switchboards

Task:

To design the layout for switchboards with capacities up to 400A per phase to comply with the requirements of the Wiring Rules' and local electricity distributor's service rules.

Why:

All switchboards must be designed to operate safely under normal operating conditions and anticipated fault conditions. Switchboard design must comply with the wiring rules, other relevant standards and local service rules.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set laboratory tasks.

3. You must achieve 100% in a final practical competency assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice (7th ed.), Pethebridge, K. & Neeson, I.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* WA Electrical Requirements:2014.
* WA Distribution Connections Manual (4th ed.) 2013
* AS/NZS 4836.2011 - Safe working practice on low-voltage electrical installations
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 9 Study Guide	G107A SGB 08/2014

Design and Layout of Switchboards

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2018 Wiring Rules

Section 2 General Arrangement, Control and Protection
Clause 2.10 Switchboards

AS/NZS 3008.1.1

Relevant Tables

Electrical Wiring Practice (7th ed.) Volume 2

Chapter 4 Switchboards, control panels and metering

WA Electrical Requirements (2014)

Section 6 Metering and service equipment

WA Distribution Connections Manual (4th ed.) 2013

Section 11 Metering

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this manual.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 9 Summary	G107A SGB 08/2014

Design and Layout of Switchboards

1. The main requirements relating to the selection of switchboards and protection equipment are contained in AS/NZS 3000 Clause 2.10, WA Distribution Connections Manual – Section 11 Metering and the WA Electrical Requirements – Section 6. It is important to consult all three publications when determining the location and accessibility of switchboards, meter panels, sub-boards and any protection requirements. AS 3439 Low Voltage Switch Gear and Control Gear Assemblies is also available and should also be consulted if necessary.

2. The type of switchboard to be installed depends on several factors, including:

    a. The number of circuits to be controlled
    b. The size and type of load to be controlled.
    c. The type of circuit protection to be provided.
    d. The location of the switchboard.
    e. The amount and type of metering required.
    f. The level and type of fault protection required.
    g. The amount and type of segregation required between components.
    h. Accessibility.

Location and Accessibility of Switchboards

3. **Location** When selecting the position of a switchboard, AS/NZS 3000 and the WA Distribution Connections Manual provide a set of guidelines/clauses to be followed. Some requirements to be considered are the amount clearance required around the board, the height of the panel, and environment aspects such as the positioning of the switchboard in relation to automatic fire sprinkler systems, fire hoses or any other services.

4. AS/NZS 3000 Clause 2.10.2.1 specifies that the switchboard should be installed in a suitable place dry and a well ventilated area unless the switchboard is protected against moisture, and that the access to the switchboard is not obstructed.

5. **Accessibility.** Accessibility relates to both the access to the switchboard itself and to exiting an switchboard area in an emergency. AS/NZS 3000 specifies that switchboards with exposed live parts should only be accessed by authorised persons (Clause 2.10.2.2).

6. AS/NZS 3000 Clause 2.10.2.2 specifies that there must be adequate space to allow access to all sides for a person to pass to enable all equipment to be effectively operated and adjusted and to enable a person to readily escape under emergency conditions.

7. The above requirements can be achieved by providing horizontal and vertical clearances that take door opening angle into consideration. AS/NZS 3000 Clause 2.10.2.2 provides further information on the exit requirements that must be provided in relation to switch-rooms.

Switchboard Terminology

8. The following terminology is commonly used in relation to large switchboards:

Incomers Incoming supply to switchboard
Cable Zones Compartments where conductors are run
Busbar Zones Areas containing busbars
Gland Plates The plates which house the cable glands.
Module A section of a switchboard that is dedicated to a particular task
Isolators Isolating switches
MCB's Miniature circuit breakers
Pan Blank metal assembly with cutouts to allow for electrical equipment to be mounted
MDB Main Distribution Board
DB Distribution Board
CFS Unit Combination fuse-switch unit
MCC Motor Control Centre
ACB Air circuit breaker
CTs Current Transformers
Segregation Separating parts of a switchboard with barriers
Escutcheon The removable front cover plates

Installation of Metering and Service Equipment

9. The WA Distribution Connections Manual (WADCM) provides the information that will determine the installation of the kilowatt hour meters used to monitor the amount of energy used by the consumer. Because there are several tariffs it is possible that there will be more than one meter to provide mounting for. The positions of the meter panel need not necessarily be adjacent to the main switchboard. Remote meters can be installed not more than 30 metres inside the property – see WADCM Section 11. 5.7.

10. The WA Distribution Connections Manual provides information on metering that will meet with the Office of Energy requirements. An example of this is Section 11.5.1 which recommends that the metering position should be along the front of the building. When addressing metering another consideration is the use of current transformers (CT's) when the load is will exceed 100 amps – see WADCM Section 11.13 LV current transformer metering.

11. Information on typical tariffs (charges for the supply of electrical energy) is available from Synergy in WA. The tariffs change from time to time. Web site: synergy.net.au

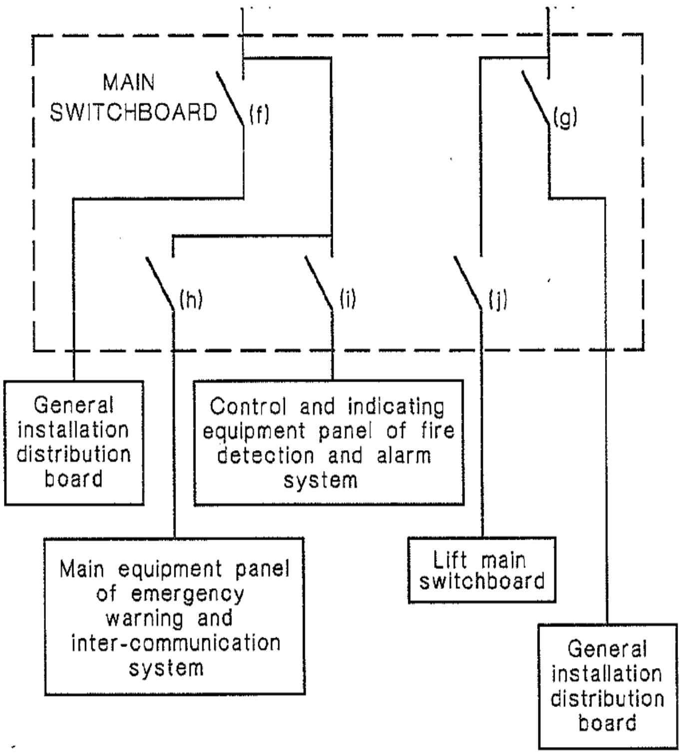
Purpose and Location of Fault Current Limiters

12. The purpose of fault current limiting devices is to interrupt the supply should a short circuit occur within the switchboard. The fault current limiters must have the capability to interrupt very high fault currents, which can reach values of thousands of amps- see Electrical Wiring Practice Volume 2; Chapter 1 page 20

13. Clause 2.5.5 of AS/NZS 3000 defines fault-current limiters as a circuit opening device designed or selected to limit the instantaneous fault current. HRC fuses are often used as an economical fault current limiter because in most cases circuit breakers do not provide sufficient protection for this purpose. Some types of circuit breakers include HRC fuses as an integral part of the assembly to provide fault current limiting and circuit protection in one unit. The service protection device (SPD) located on the consumer's meter board can be considered as a fault limiter. The WAER states the SPD must be able to protect the electrical installation from the effect of a short circuit fault of up to 25kA (see WAER clause 6.2.3.1)

Safety Services

14. Most large electrical installations has safety services such as; fire detection and fire-fighting systems, evacuation systems and lifts. These safety services must be controlled separately from the main switch(es) controlling general electrical services in the building. By controlling safety services independently, is to ensure that the electrical supply is not inadvertently disconnected from electrical equipment that is required to operate during emergency conditions.



Control of Electrical Services on a Main Switchboard

Note:
Main switches f & g control general electrical services – switched off in an emergency
Main switches h, i & j separately control various safety services

Fire Pumps

15. Fire pumps are used in fire-fighting emergencies and the AS/NZS 3000 Wiring Rules provides information in Section 7.2 on allowable wiring systems and control of these circuits.

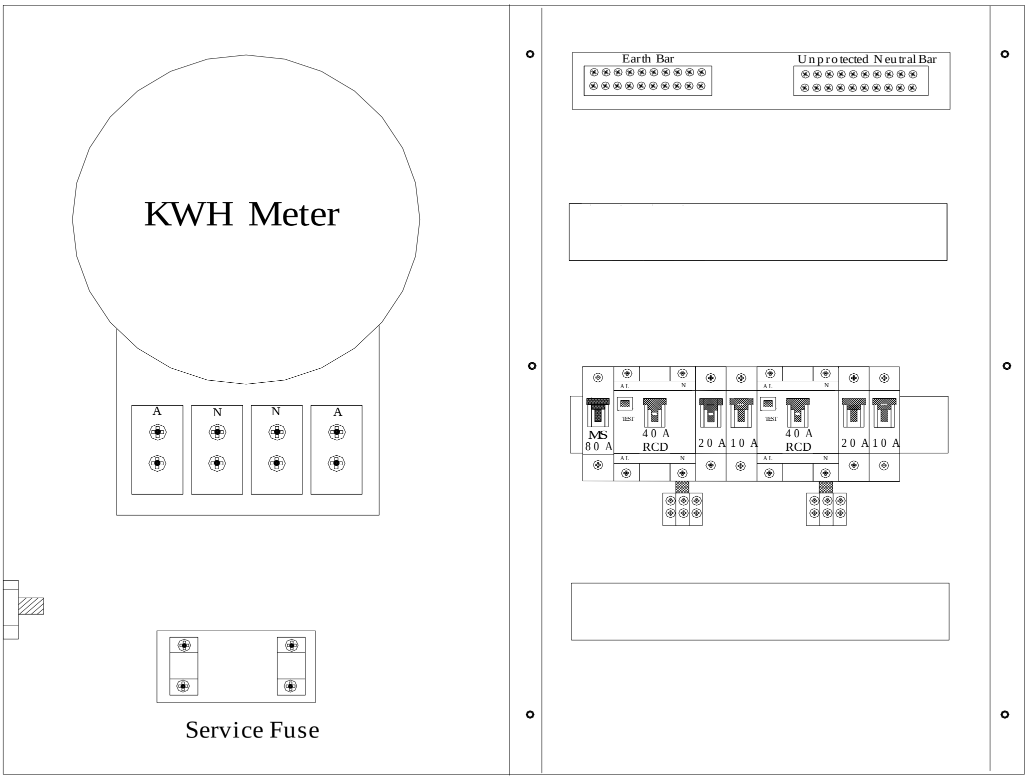
Types of Switchboard

16. The types of switchboards used in non-domestic installations vary widely according to the type of installation, but the main general classifications are:

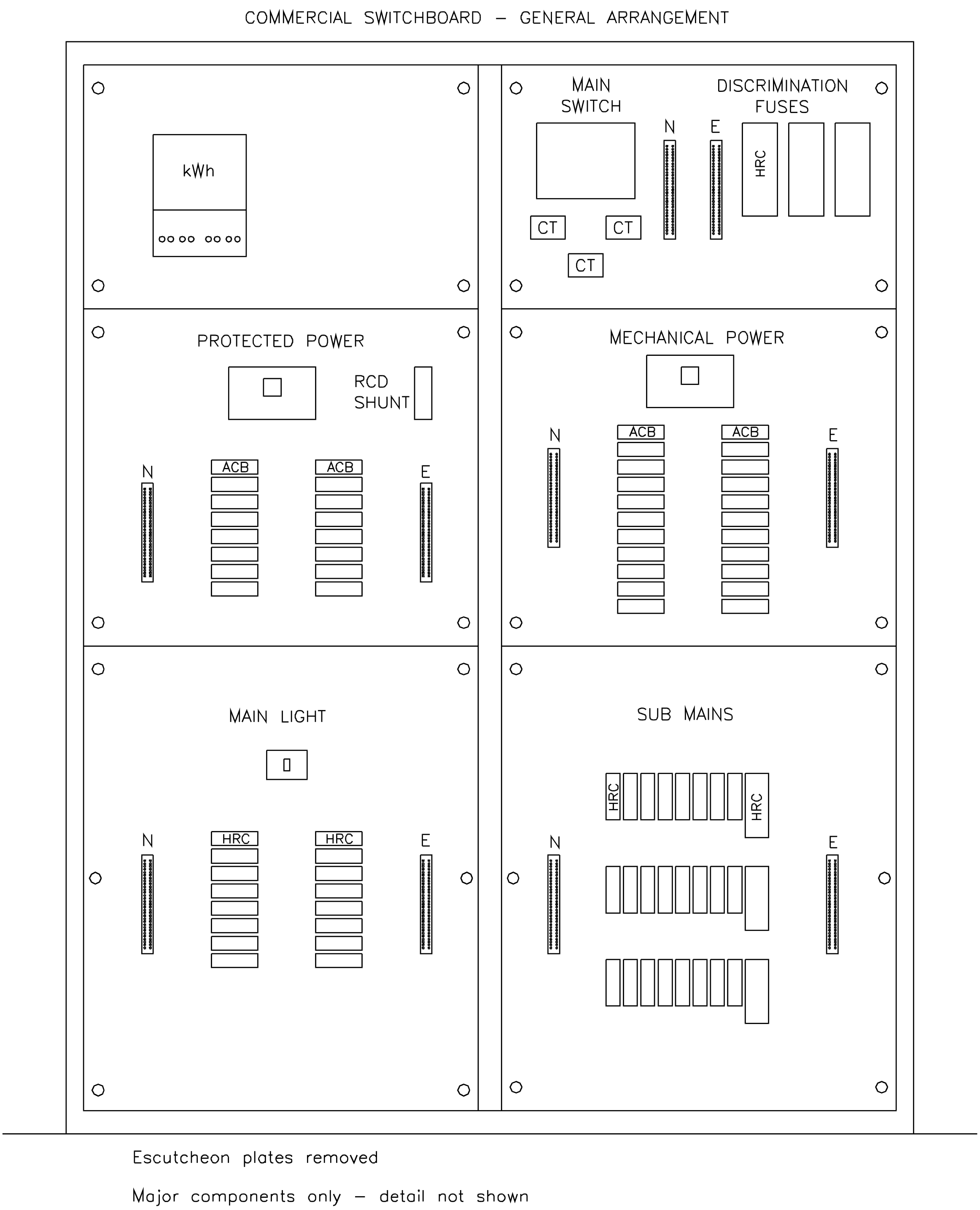
a. Open-type assembly. Live parts are accessible so they can only be used in situations where access is by authorised persons only (older installations).
b. Dead front assembly. No live parts are accessible from the front, but they may be accessible to authorised persons from other directions.
c. Cubicle type. Components are contained in one or more enclosed metal cubicles - usually free standing.
d. Desk type. Components are enclosed in a desk so that an operator can control process from a seated position if required.
e. Box type assembly. Components are contained in adjoining boxes which can be sealed for use in hazardous areas.

17. The general arrangements for switchboards are shown on the following pages.

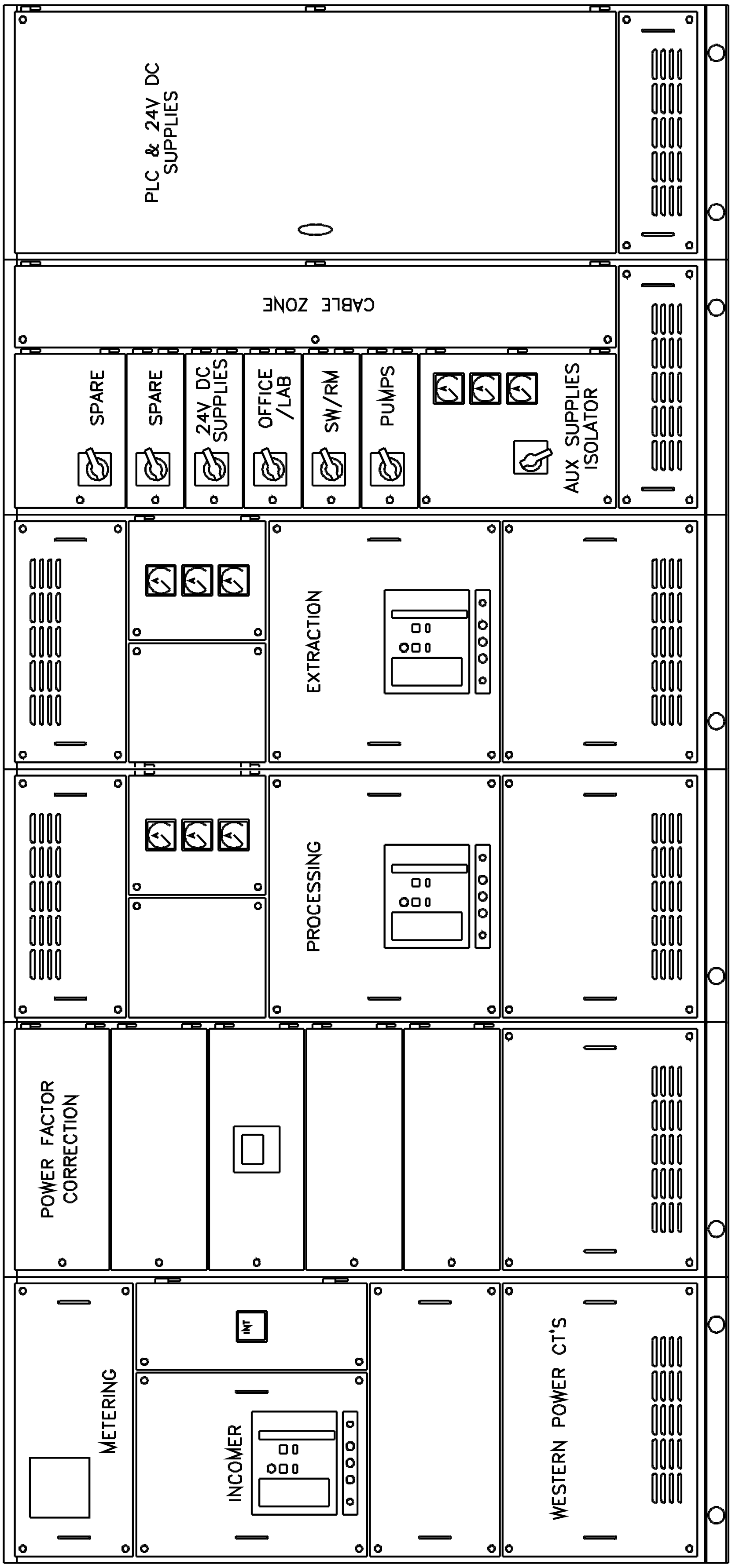
Domestic Switchboard



Commercial


COMMERCIAL SWITCHBOARD – GENERAL ARRANGEMENT
kWh
MAIN SWITCH
DISCRIMINATION FUSES
N
E
HRC
CT
CT
CT
PROTECTED POWER
RCD SHUNT
N
ACB
ACB
E
MECHANICAL POWER
N
ACB
ACB
E
MAIN LIGHT
N
HRC
HRC
E
SUB MAINS
HRC
HRC
N
E
Escutcheon plates removed
Major components only – detail not shown

Industrial



Sample Industrial Switchboard – General Arrangement

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 9 Worksheet 1	G107A SGB 08/2014

Design and Layout of Main Switchboards

1. Which three publications determine the position of an electrical switchboard?

2. What publication and in which section is the physical location of switchboards location determined?

3. State the three main considerations when choosing a suitable position for a main switchboard? Give the AS/NZS 3000 Clause number(s)

4. When determining the requirements for marking an enclosure or door of an electrical switchboard, when would it NOT be necessary to mark the door in a commercial establishment?

5. Is it permissible to install a switchboard in a fire isolated stair well?
Give the AS/NZS 3000 Clause number.

6. What is the general requirement of AS/NZS 3000 in relation to the accessibility of switch boards? Give the Clause number.

7. What are the three requirements to assist in providing sufficient clearance around a switchboard? Give the AS/NZS 3000 Clause number.

8. Under emergency evacuation conditions, what is the minimum number of exits that must be provided for a switchboard that is 3.5 metres long? Give the AS/NZS 3000 Clause number.

9. Can the Main Switch used to control general light and power also be used to control a fire pump circuit? Give the AS/NZS 3000 Clause number.

10. What locking requirements apply to isolating switches connected to circuits supplying fire hydrant booster pumps? Give the AS/NZS 3000 Clause number.

11. Where a fire hydrant booster pump is fitted with thermal overload protection, what minimum setting is required for the overload device? Give the AS/NZS 3000 Clause number.

12. Is it permissible to install the cabling for emergency services in the same conduit as cabling associated with general power systems? Give the AS/NZS 3000 Clause number.

13. Sketch the front view of a main switchboard for a typical single phase domestic installation. Label all electrical components.

14. Sketch the front view of a typical industrial three phase main switchboard connected for a 300 amp maximum demand with the following loads:

    4 Lighting circuits (general purpose)
    7 10 amp 240 volt socket outlet circuits
    3 15 amps 1 phase socket outlet circuits
    6 20 amp 3 phase socket outlet circuits
    8 20 amp 3 phase fixed equipment circuits

Government of Western Australia North Metropolitan TAFE	**Select wiring systems and cables for LV general electrical installations**	Section 9 Worksheet 2	G107A SGB 08/2014

Switchboard Layout Project

Objective

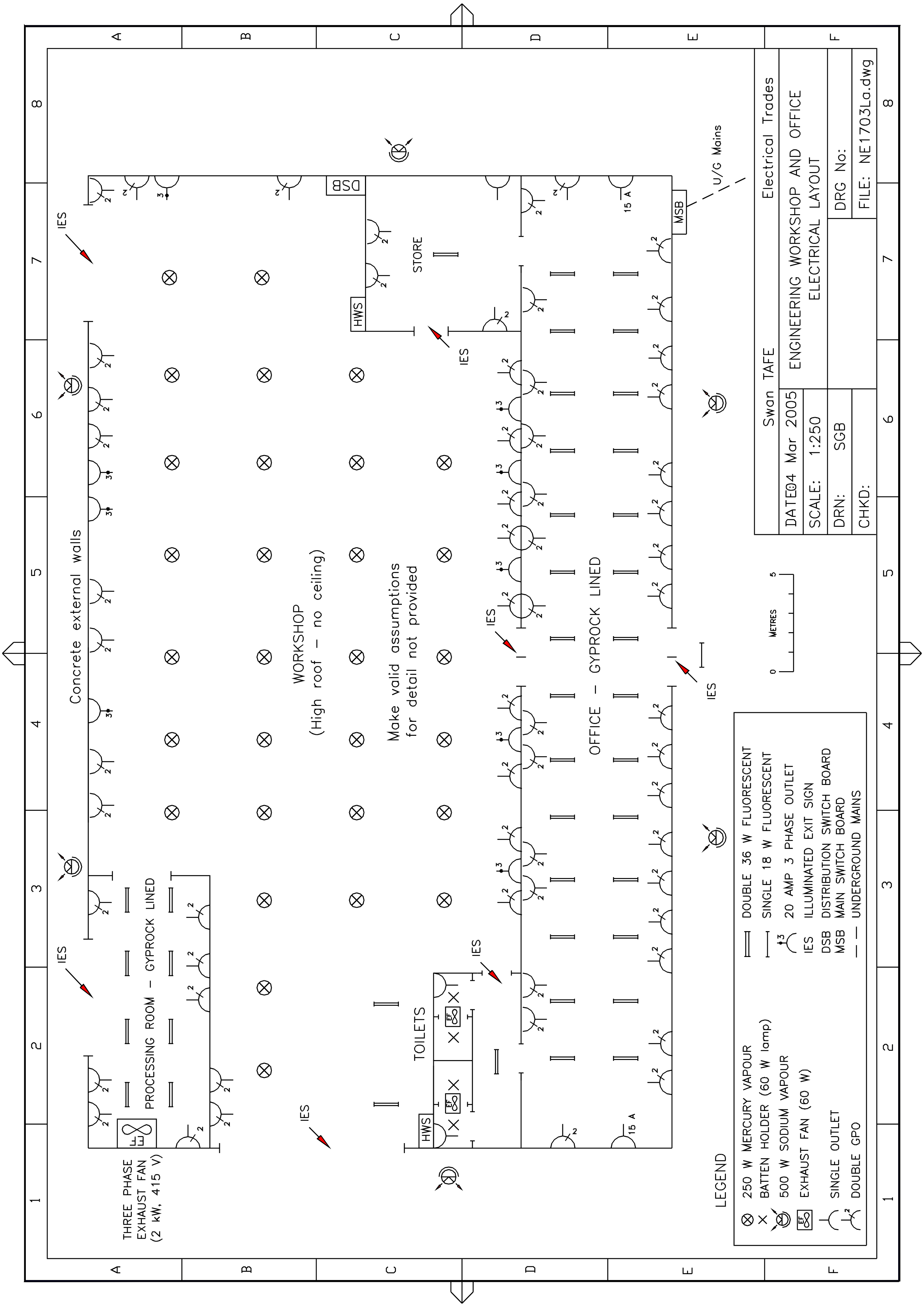
To design and draw the layout of a non-domestic switchboard showing the location of all components including all control, protection and metering components.

Equipment

AS/NZS 3000:2018 - Wiring Rules.
AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
WA Electrical Requirements
Manufacturers' catalogues as required.
5 mm square graph paper.
Maximum demand calculation sheet.

Procedure

1. Examine the drawing and specifications provided. Make valid assumptions for detail not given.
2. Calculate the maximum demand for the installation.
3. Select the cable for the consumers mains and check volt drop.
4. Select the cable for the submains and check volt drop.
5. Specify final subcircuits, cables and protective devices. Check the volt drop to the three phase exhaust fan in the Processing Room.
6. Design and sketch the main switchboard. Show the layout of all equipment (approximately to scale) on the switchboard. Use manufacturer's catalogues or actual components to determine their size. Provide an appropriate legend for the switchboard on a separate sheet.
7. Design and sketch the sub-switchboard.
8. Submit your project to your Lecturer for comment and assessment.
9. Add this completed project to your design portfolio.


Concrete external walls
WORKSHOP
(High roof – no ceiling)
Make valid assumptions
for detail not provided
OFFICE – GYPROCK LINED
PROCESSING ROOM – GYPROCK LINED
TOILETS
STORE
THREE PHASE
EXHAUST FAN
(2 kW, 415 V)
DSB
MSB
HWS
IES
U/G Mains
METRES
LEGEND
250 W MERCURY VAPOUR
BATTEN HOLDER (60 W lamp)
500 W SODIUM VAPOUR
EXHAUST FAN (60 W)
SINGLE OUTLET
DOUBLE GPO
DOUBLE 36 W FLUORESCENT
SINGLE 18 W FLUORESCENT
20 AMP 3 PHASE OUTLET
IES ILLUMINATED EXIT SIGN
DSB DISTRIBUTION SWITCH BOARD
MSB MAIN SWITCH BOARD
UNDERGROUND MAINS
Swan TAFE
Electrical Trades
ENGINEERING WORKSHOP AND OFFICE
ELECTRICAL LAYOUT
DATE: 04 Mar 2005
SCALE: 1:250
DRN: SGB
CHKD:
DRG No:
FILE: NE1703La.dwg

Specifications:

1. Steel framed building 5 metres high with 3 metre ceiling in office, processing room, toilets and store.

2. Consumers mains are 15 metres long.

3. Hot water systems: Three phase, 15 amp instantaneous type.

4. Assume the 2 kW exhaust fan in the Processing Room draws 4 amps.

5. Separate areas:

    a. Workshop
    b. Main office
    c. Store
    d. Processing room
    e. Toilets
    f. External lighting

6. Double fluorescent luminaires 0.6 amps.

7. Single fluorescent luminaires 0.25 amps.

8. Illuminated exit sign lights 0.25 amps.

9. Minimum cable size: Lighting: 1.5 mm^2 TPS. Power: 2.5 mm^2 TPS.

10. Conduits in concrete slab where possible.

11. Main earth electrode directly below Main Switchboard

Answer Sheet for Installation Design:

Item	Answer
Minimum current carrying capacity consumer's mains in WA according to WAER	
Maximum demand consumer's mains.	
Minimum size conductor consumer's mains, based on current carrying capacity	
Minimum size conductor consumer's mains, based on volt-drop	
Size of cable selected for consumer's mains	
Actual volt-drop of consumer's mains	
Minimum size conductor main earth	
Minimum size cable for selected final sub-circuit, based on current carrying capacity	
Minimum size cable for selected final sub-circuit, based on volt-drop	
Size of cable for the selected final sub-circuit	
Actual volt-drop of selected final sub-circuit	
Maximum fault loop impedance of the final sub-circuit.	
Size type-C circuit breaker of the final sub-circuit, based on AS/NZS 3000 clause 2.5.3.1	

Maximum Demand Calculation Table (Single or Three Phase)

Load Group	Load	Remarks	Calculations	Contribution per phase (amps)		
				R	W	B