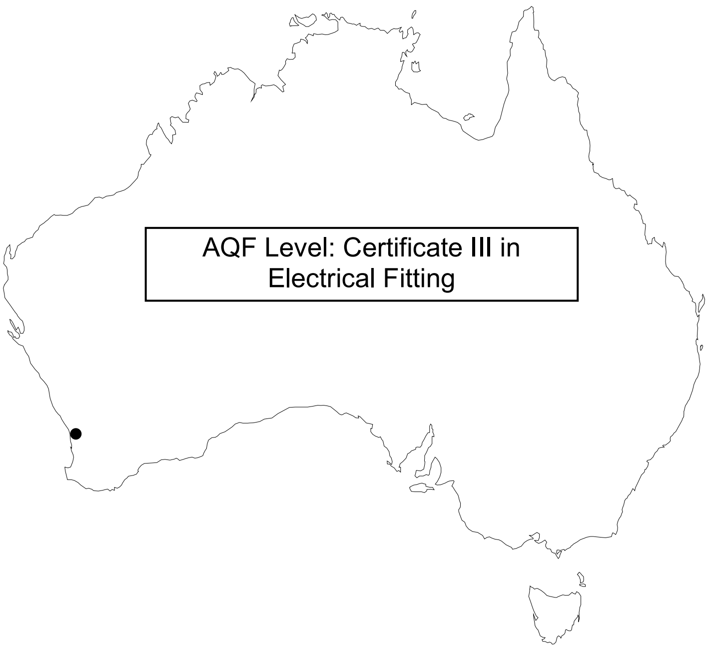
Government of **Western Australia**
North Metropolitan **TAFE**

Electrical Fitter Revision Program

Review Questions



North Metropolitan TAFE
Version 4.1, Nov 2021

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Acknowledgements

This Unit Guide has been prepared by NMTAFE Lecturers.

It is intended for NMTAFE students only.

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EFRP – Electrical Fitter Revision Program

CONTENTS

EFRP – Electrical Fitter Revision Program

C O N T E N T S

SECTION 3

Preface

Introduction

The Electrical Fitting Training program is arranged to provide eligible tradespersons with the opportunity to review selected aspects of their previous electrical training and become familiar with local regulatory requirements in preparation for formal assessments of their ability to demonstrate competency.

To be eligible to enrol for this course you must have a working knowledge of both written and verbal English, and you must have written permission from Energy Safety WA, to indicate that you have produced satisfactory evidence of your previous electrical trade training.

Course Structure

This course is designed to be delivered as a full time two week Block.

References:

Candidates will be provided copies of "Resources Notes" but are required to provide their copies of **CURRENT EDITIONS** (with amendments) of the following publications:

AS/NZS 3000 Wiring Rules

The following general electrical references are strongly recommended:

Electrical Trade Principles (Jeffery Hampson)
Electrotechnology Practice (Jeffery Hampson)
Australian Electrical Wiring Volume 1 (Pethebridge and Neeson)
Australian Electrical Wiring Volume 2 (Pethebridge and Neeson)
Electrical Principles for the Electrical Trades (J. R. Jenneson)
WA Electrical Requirements (Energy Safety WA)
Western Australian Distribution Connection Manual

Reference to other publications and relevant Australian Standards will be made during the course.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program	Orientation	

1. Orientation

Welcome to this College. So that you may make use of the facilities at this College your Lecturer will indicate the location of the following:

a. Classrooms
b. Workshops, laboratories and tool stores
c. Library Resource Centre
d. Bookshop
e. Administration block
f. Toilet blocks
g. Student parking areas
h. Cold water drinking facilities
i. First-aid Centre (unattended, except by arrangement)
j. Cafeteria
k Notice boards
l. Location of emergency stop buttons
m. Location of fire extinguishers
n. Telephones for private calls
o. Telephones for emergency calls to the college switchboard
p. Emergency evacuation warning signal
q. Manager's office

2. College Hours

<u>Block Attendances</u>

Monday to Friday 8.00 am to 4.45 pm (1 week)

Library Resource Centre hours: ______________________________

Bookshop hours: ______________________________

Emergency Procedures

3. When the emergency alarm is sounded you are required to immediately stop what you are doing and move as quickly as possible (without running) to the area described by your Lecturer. Evacuation drills may be carried out at any time during the course.

4 If you are injured whilst attending classes at this college, report immediately to your Lecturer. If your Lecturer is not readily available to advise any other member of the college staff or ring the main college switchboard. The First-Aid Officer is ______________________ .

Safety

5. Proper footwear must be worn during all on-campus classes (thongs are not acceptable). Clothing must cover the upper part of the body (singlets and tank-tops are not acceptable).

Steel-capped boots (safety footwear) must be worn in all electrical laboratories /workshops.

Eye protection must be provided by the student and worn in all workshop areas.

Class Requirements

6. You will require the following items for each class attendance unless otherwise indicated by your Lecturer:

Resource books (as indicated by your Lecturer) in a two-ring file.
Pen, pencil, 300 mm rule, eraser.
About 50 sheets of ruled A4 paper.
Scientific calculator.

Student Handbook

7. The Student Handbook contains information relating to college facilities, policies and requirements - a copy will be made available to you at the start of the course.

Lecturer: ____________________________ Telephone: ______________

Notes:

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Practical Task List	Version 4 2021

EFRP - Practical Tasks

All of the following practical tasks are to be completed at least once during the course.

Additional specifications will be provided by the lecturer as required.

#	Practical Tasks	Signature	Date
1.	Perform CPR on a manikin-one operator.		
2.	Perform a safety audit in a workplace using a given checklist.		
3.	Conduct a risk assessment and perform an isolation procedure.		
4.	Select suitable fire extinguishers for the given conditions.		
5.	Test four different single insulated (Class **I**) portable appliances for safety.		
6.	Test a double insulated (Class **II**) portable appliance for safety.		
7.	Manufacture a single-phase extension cord and test it for compliance and safety.		
8.	Use the Zelio Soft 2 program to Design a working program, build and connect the power and control circuit for a three-phase FWD & REV Starter.		
9.	Connect an FWD & REV Starter to a VSD		
10.	Build and connect the power and control circuit for a three-phase STAR/DELTA Starter.		
11.	Use the Zelio Soft 2 program to Design a working program, build and connect the power and control circuit for a three-phase STAR/DELTA Starter.		
12.	Test Motors for serviceability		
13.	Test Transformers for serviceability		
14.	Test electrical appliances for safety and compliance with requirements.		
15.	Test electrical motors for safety compliance with requirements.		
16.	Test transformers for safety compliance with requirements.		

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary 1-1	Version 4.1 2021

1.1 - Occupational Safety and Health Act

The Occupational Safety and Health Act 1984 is an Act of the W.A. Parliament that is intended mainly to promote and improve standards for occupational safety and health. The Act details the legal responsibilities of various groups and individuals in matters relating to occupational safety and health and establishes the WorkSafe WA Commission to administer the Act. The paragraphs which follow are abbreviated extracts from the Act.

Duties of Employers (Para 19)

1. An employer shall, so far as is practicable, provide and maintain a working environment in which employees are not exposed to hazards and in particular, but without limiting the generality of the foregoing, an employer shall -

   a. provide and maintain workplaces, plant, and systems of work such that, so far as is practicable, the employees are not exposed to hazards;

   b. provide such information, instruction, and training to, and supervision of, the employees as is necessary to enable them to perform their work in such a manner that they are not exposed to hazards;

   c. consult and co-operate with safety and health representatives if any, and other employees at the workplace, regarding occupational health, safety and welfare within the workplace.

   d. where it is not practicable to avoid the presence of hazards at the workplace, provide the employees with, or otherwise provide for the employees to have, such adequate personal protective clothing and equipment as is practicable to protect them against those hazards, without any cost to the employees; and

   e. make arrangements for ensuring, so far as is practicable, that -

      (i) the use, cleaning, maintenance, transportation and disposal of plant; and

      (ii) the use, handling, processing, storage, transportation and disposal of substances.

   at the workplace is carried out in a manner such that the employees are not exposed to hazards.

Duties of Employees (Para 20)

2. An employee shall take reasonable care -

   a. to ensure his/her safety and health at work; and

   b. to avoid adversely affecting the safety or health of any other person through any act or omission at work.

3. Without limiting the generality of subsection (1), an employee contravenes that subsection if he/she -

   a. fails to comply, so far as he is reasonably able, with instructions given by the employer for his/her safety or health or the safety or health of other persons;

b. fails to use such protective clothing and equipment as is provided, or provided for, by the employer as mentioned in section 19 (1) d., in a manner in which he/she has been properly instructed to use it;

c. misuses or damages any equipment provided in the interests of health, safety or welfare; or

d. fails to report forthwith to his/her employer -

(i) any situation at the workplace that he/she has reason to believe could constitute a hazard to any person and he/she cannot him/herself correct; or

(ii) any injury or harm to the health of which he/she is aware that arises in the course of, or connection with, his/her work.

4. An employee shall co-operate with his/her employer in the carrying out by his/her employer of the obligations imposed on him/her under this Act.

Terms of Office (Para 32)

5. A person who is elected as a safety and health representative holds office, subject to the Act, for a term of 2 years.

Functions of Safety and Health Representatives (Para 33)

6. The functions of a safety and health representative are, in the interests of safety and health at the workplace for which he/she was elected -

a. to inspect the workplace or any part of it-

(i) at such times as are agreed with the employer, or

(ii) where he/she has not inspected the workplace, or part of it, for the preceding 30 days, at any time upon giving reasonable notice to his/her employer;

b. immediately, in the event of an accident, a dangerous occurrence, or a risk of imminent and serious injury to, imminent and serious harm to the health of, any person, to carry out an appropriate investigation in respect of the matter;

c. to keep him/herself informed as to the safety and health information provided by his/her employer in accordance with the Act, and liaise as necessary with the department and other Government and private bodies;

d. forthwith to report to the employer any hazard or potential hazard to which a person is, or might be, exposed at the workplace that comes to his/her notice;

e., where there is a safety and health committee for the workplace, to refer to it any matters that he/she thinks, should be considered by the committee;

f. to consult and co-operate with his employer on all matters relating to the safety and health of persons in the workplace;

g. liaise with the employees regarding matters concerning the safety or health of persons in the workplace.

7. **Para 31(8)** A person is not eligible to be elected as a safety and health representative for a workplace unless -

   a. he/she is an employee who works at the workplace; and

   b. he/she has -

      (i) been continuously employed by the employer concerned during the preceding 2 years; or

      (ii) had a total of at least 2 years' experience in work of a similar nature to the work he does at the workplace; or

      (iii) had such training, if any, as is agreed under section 30 as being adequate for the purposes of this paragraph; or

      (iv) been approved by the Commissioner for the purposes of this paragraph.

Establishment of Safety and Health Committees (Para 37)

8. An employer shall, in accordance with this Part and the regulations, establish a safety and health committee within 3 months of -

   a. the coming into operation of a regulation requiring him/her to do so;

   b. service on him/her of a notice from the Commissioner requiring him/her to do so; or

   c. being requested under section 36 (1) to do so, unless, in the case mentioned in paragraph c., the Commissioner has decided that a safety and health committee should not be required to be established.

The composition of Safety and Health Committees (Para 38)

9. A safety and health committee for a workplace shall consist of -

   a. the safety and health representatives, if any;

   b. if there are no safety and health representatives, the person or persons elected by the employees for the purposes of this section; and

   c. the person or persons nominated by the employer for the purposes of this section.

Request for Safety and Health Committee (Para 36(1))

10. An employee who works at a workplace may request the employer to establish a safety and health committee for the workplace under this Part.

Functions of Safety and Health Committees (para 40)

11. The functions of a safety and health committee are -

   a. to facilitate consultation and co-operation between an employer and the employees in initiating, developing and implementing measures designed to ensure the safety and health of employees at the workplace;

b. to keep itself informed as to standards relating to safety and health generally recommended or prevailing in workplaces of a comparable nature and to review, and make recommendations to the employer on, rules and procedures at the workplace relating to the safety and health of the employees;

c. to recommend to the employer and employees the establishment, maintenance, and monitoring of programmes, measures and procedures at the workplace relating to the safety and health of the employees;

d. to keep in a readily accessible place and form such information as is provided under this Act by the employer regarding the hazards to persons that arise or may arise at the workplace;

e. to consider, and make such recommendations to the employer as the committee sees fit in respect of, any changes or intended changes to or at the workplace that may reasonably be expected to affect the safety or health of employees at the workplace;

f. to consider such matters as are referred to the committee by a safety and health representative; and

g. to perform such other functions as may be prescribed in the regulations or given to the committee, with its consent, by the employer.

Powers of Inspectors (Para 43)

12. An inspector may, for the purposes of this Act -

a. at all reasonable times of the day or night, enter, inspect and examine any workplace;

b. enter any workplace at any other time that the performance of his/her functions under this Act requires such entry;

c. when entering any workplace, take with him/her such equipment and materials as he/she considers appropriate;

d. conduct such examination and inquiry as he/she considers necessary to ascertain whether there has been compliance with this Act;

e. examine any plant, substance or another thing whatsoever at the workplace;

f. take and remove samples of any substance or thing, without paying for it;

g. take possession of any plant or thing for further examination or testing or use as evidence;

h. take photographs and measurements, and make sketches and recordings;

i. require the production of, examine, and take copies of extracts of, any document;

j. require the workplace, or any part of it, be left undisturbed for as long as is specified in the requirement;

k. interview, either in private or otherwise, as he/she considers appropriate, any person whom he/she finds at a workplace or whom he/she has reasonable grounds to believe is, or was at any time during the preceding 2 years, an employee working at the workplace;

l. require any person whom he/she interviews under paragraph (k) to answer any questions put to him/her and, if the inspector considers it appropriate, to verify any such answer by statutory declaration;

m. require any person to state his/her name and address;

n. require the employer or any person who works at a workplace to render such assistance to the inspector as the inspector considers necessary for the performance of his function under this Act;

o. exercise such other powers as may be conferred in him/her by the regulations or as may be necessary for the performance of his/her functions under the Act.

Improvement Notices (Para 48)

13. Where an inspector is of the opinion that any person -

a. is contravening any provision of this Act; or

b. has contravened a provision of this Act in circumstances that make it likely that the contravention will continue or be repeated, the inspector may issue to the person an improvement notice requiring the person to remedy the contravention or likely contravention or the matters or activities occasioning the contravention or likely contravention.

14. An improvement notice shall -

a. state that the inspector is of the opinion that the person -

(i) is contravening a provision of this Act; or

(ii) has contravened a provision of this Act in circumstances that make it likely that the contravention will continue or be repeated;

b. state reasonable grounds for forming that opinion;

c. specify the provision of this Act in respect of which that opinion is held;

d. specify the time before which the person is required to remedy the contravention or likely contravention or the matters or activities occasioning the contravention or likely contravention; and

e. contain a brief summary of how the right to have the notice reviewed, given by sections 51 and 51A, may be exercised.

Prohibition Notices (Para 49)

15. Where an inspector is of the opinion that an activity is occurring or may occur at a workplace which activity involves or will involve a risk of imminent and serious injury to, or imminent and serious harm to the health of, any person, the inspector may issue to the person who has or may be reasonably presumed to have control over the activity a prohibition notice prohibiting the carrying on of the activity until an inspector is satisfied that the matters which give or will give rise to the risk are remedied.

Offences by Bodies Corporate (Para 55)

16. Where a body corporate is guilty of an offence under this Act and it is proved that the offence occurred with the consent or connivance of, or was attributable to any neglect on the part of, any director, manager, secretary or another officer of the body, or any person who was purporting to act in any such capacity he, as well as the body corporate, is guilty of that offence.

Discrimination (Para 56)

17. An employer or prospective employer who in any way treats an employee or prospective employee less favourably than he/she otherwise would, by reason only that the employee or prospective employee -

a. is or has been a safety and health representative or a member of a safety and health committee;

b. performs or has performed any function as a safety and health representative or a member of a safety and health committee;

c. gives or has given assistance or information to an inspector, safety and health representative or any member of a safety and health committee;

d. makes or has made a complaint in relation to health, safety or welfare to a person who is or was his/her employer or fellow employee or an inspector, a safety and health representative or a member of a safety and health committee, commits an offence.

General Penalty (Para 54)

18. A person who commits an offence against this Act is liable if a penalty is not expressly provided for that offence -

a. where the offence is committed by a person as an employee – a fine of $5 000 and,

b. in any other case - a fine of $25 000.

Exclusion from the Act

19. Two general areas of industry are specifically excluded from the provisions of the Occupational Safety and Health Act in Western Australia because they are the subject of other specific legislation. The two general areas are the mining industry and the petroleum industry. The exclusions are described in the Occupational Safety and Health Act - Para 4 (2).

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Review Questions	Version 4
Electrical Trades	EFRP Section 1	1-1	2021

Occupational Safety and Health Act

1. How does the Occupational Safety and Health Act benefit you as an employee?

2. What is meant by the term 'duty of care' in relation to Occupational Safety and Health?

3. List FOUR 'duties of care' which are the responsibility of the employer in relation to Occupational Safety and Health?

4. List FOUR 'duties of care' which are the responsibility of the employee in relation to Occupational Safety and Health?

5. What is the main general aim of the Occupational Safety and Health Act in W.A.?

6. What qualifications and experience must an applicant for the position of OSH Safety Representative have? Give three factors.

7. What is the general penalty if an individual employee commits an offence against the Occupational Safety and Health Act?

8. What is the general penalty if an employer commits an offence against the Occupational Safety and Health Act?

9. Worksafe WA inspectors are empowered to issue two types of notices if they are of the opinion that the Occupational Safety and Health Act is being contravened. What are the names given to each of the notices?

10. What two actions must an employee take if he or she becomes aware of a hazardous situation?

11. What are the titles of the TWO legislative publications which deal with matters directly related to occupational safety and health in Western Australia?

12 What is the name of the body which is responsible for the administration of safety and health legislation in Western Australia?

13. List four of the powers of a Worksafe WA inspector.

ANSWERS PAGE 205

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 1	1-2	2021

1.2 - Electrical Requirements of OSH Regulations (1996)

The Occupational Safety and Health Act Regulations (1996) include regulations specific to particular skill groupings. The material which follows consists of abbreviated extracts from the main Regulations relating to electrical work (Division 6 - Electricity). The regulation from which the material was extracted is indicated. The requirements of the OSH Regulations are in addition to those in the Wiring Rules.

Occupational Safety and Health Regulations

Division 6 - Electricity

Definition:

3.58. In this Division -

"Supply authority" has the same meaning that it has in the Electricity Act 1945,

and, for this Division, a reference in AS/NZS 3012 to a supply authority is to be treated as a reference to a supply authority as defined in this regulation.

3.59. A person who, at a workplace, is an employer, the main contractor, a self-employed person or a person having control of the workplace, must ensure that -

(a) all electrical installations at the workplace are designed constructed, installed, protected, maintained and tested to minimize the risk of electrical shock or fire; and

(b) each connection on a flexible cord, that is installed or renewed at the workplace after 1 October 1996, is of either the moulded one part non-rewireable or transparent type.

Penalty: $25,000.

Protection against earth leakage current

3.60. (1) A person who, at a workplace other than one to which AS/NZS 3012 applies, is an employer, a self-employed person or a person having control of the workplace, must ensure -

(a) where electricity is supplied to hand-held or portable equipment through a fixed socket at the workplace, that after 1 September 1997 -

(i) the final sub-circuit to which the fixed socket is connected is protected by a non-portable residual current device; or

(ii) the output side of the fixed socket is directly connected to a portable residual current device; and

(b) any residual current device installed at the workplace is kept in a safe working condition and tested regularly to ensure its continued effective operation.

Penalty: $25,000

(2) This regulation does not apply to a workplace at which the supply of electricity -

(a) does not exceed 32 volts alternating current;
(b) is direct current
(c) is provided through an isolating transformer complying with AS/NZS 3108; or
(d) is provided from the unearthed outlet of a portable generator.

Electrical installations on construction sites etc.

3.61. If work of a type referred to in clause 1.2 of AS/NZS 3012 is to be done then a person who, in relation to the workplace, is an employer, the main contractor or a self-employed person must ensure that -

(a) the requirements of AS/NZS 3012 or complied with in relation to matters within the scope of AS/NZS 3012 except Clause 2.3.5 of that Standard;

(b) each socket outlet provided on a switchboard for the connection of portable appliances and equipment is individually controlled by a double pole switch or another device that provides the same level of safety as a double pole switch; and

(c) no aerial cable is fixed onto, or attached to, a scaffold.

Penalty: $25.000

Tester to record licence number on the tag

3.62. A person who conducts under Clause 3.6, 3.7 or 3.8 of AS/NZS 3012 a test on an item of portable electrical equipment, or a portable residual current device that is intended for use at a workplace, must ensure that in addition to the information referred to in Clause 3.9.2 of that Standard, the tag bears the person's Licence Number as an electrical worker under the Electricity Act 1945.

Penalty: $2,000

Records of electrical equipment test results to be provided

3.63. If a person brings into a workplace to which regulation 3.61 applies, an item of portable electrical equipment or a portable residual current device required under AS/NZS 3012 to be tested, then that person must, before the item or device is used at the workplace -

(a) provide the main contractor with a record of the relevant testing data under that Standard for the item or device; and

(b) ensure that the tag bears the licence number of the electrical worker who conducted the test.

Penalty: $2,000

Restrictions on working in the vicinity of electrical wires

3.64. (1) A person who, at a workplace is an employer, the main contractor a self-employed person or a person having control of the workplace, must ensure -

(a) that no work is done above overhead electric wires;

(b) that no work is done on or adjacent to a metal scaffold -

(i) that is less than 4.5 metres horizontally from; or
(ii) that is less than 6 metres or below, overhead electric wires;

(c) without limiting Clause 2.5.7 of AS/NZS 3012, that where practicable, no plant is used -

(i) within 2 metres of overhead electric distribution wires;

(ii) within 6 metres of overhead electric transmission wires; or

(iii) in any manner by which the plant could reach an aerial conductor;

and

(d) that as far as practicable, no person, other than a person who is authorized to do so under the Electricity Act 1945, comes into contact, through any medium, with live electric wires at the workplace.

Penalty: $25,000

(2) A person does not commit an offence under sub-regulation (1) if, proof of which is on the person -

(a) the electric wires have been adequately insulated and effectively cordoned off to protect the safety of persons or otherwise made safe, as the case requires; and

(b) the action, if any, required by the supply authority to be taken to make the wires safe, has been taken.

Connecting electricity to construction sites

3.65. The main contractor at a construction site must ensure if it is practicable to do so, that by the time when work on the site has reached plate height or the equivalent, electricity has been supplied to the site from a supply authority's service line or service cable by way of a temporary or permanent connection.

Penalty: $10,000

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-2	Version 4 2021

Electrical Requirements of OSH Regulations

1. Which Standard is used to define a Supply Authority in the OSH Regulations (Division 6 Electricity)?

2. Which Clause in the OSH Regulations (Division 6 Electricity) identifies the person responsible for the testing of an electrical installation ensuring its compliance with all safety aspects?

3. With reference to Question 2, WHO is responsible and WHAT is the Penalty for failure to comply with this Clause?

4. Which Clause in the OSH Regulations (Division 6 Electricity) covers the protection against earth leakage current?

5. Under certain conditions, there are exemptions to the Clause stated in Question 4. List TWO of these exemptions.

6. According to the OSH Regulations (Division 6 Electricity) can an aerial cable be fixed onto a scaffold? State the Clause number to justify your answer.

7. If a person conducts a test on an item of portable electrical equipment, what is he/she required to do in compliance with OSH Regulations (Division 6 Electricity)? State the TWO requirements.

8. If a person brings a portable residual current device onto a construction site, what conditions must be met to satisfy the OSH Regulations (Division 6 Electricity)?

9. State TWO restrictions the OSH Regulations (Division 6 Electricity) specify when working in the vicinity of overhead electrical cables.

10. a. Which Clause in the OSH Regulations directs the connecting of electricity to construction sites?

    b. Who is responsible to ensure this connection?

    c. By what time must this be completed?

ANSWERS PAGE 206

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary 1-3	Version 4.1 2021

1.3 - Industrial Safety

1. Safety is a process that results in the avoidance of injury to individuals or groups, and the avoidance of damage to equipment or machinery. The following notes are a summary of the most important facts and procedures relating to general safety in situations in which electrical tradespersons may be required to work. More specific aspects of safety are covered during appropriate parts of the course.

2. Safety considerations apply to:

   a. The individual.
   b. The machine being operated.
   c. The equipment or workpiece on which work is being done.

3. The PRIMARY responsibility for safety in the workplace rests with the INDIVIDUAL. It is the individual's responsibility to ensure that:

   a. Conditions under which he/she is working are safe for himself/herself and others in the vicinity.

   b. His/her actions are safe.

Main Causes of Accidents

4. The two most common causes of accidents are unsafe acts and unsafe working conditions. If an accident occurs it is usually because someone commits an unsafe act or because an unsafe condition is allowed to go unreported and uncorrected.

Unsafe Acts

5. Any act which could result in injury or damage is considered to be unsafe. Unsafe acts include:

   a. Lifting incorrectly.
   b. Using a ladder without adequate support.
   c. Using metal removing machinery without eye protection
   d. Drilling without adequate support for the workpiece.
   e. Handling chemicals without personal protection.
   f. Skylarking in a workshop.
   g. Failing to correct or report an unsafe condition.
   h. Using hand tools incorrectly.
   i. Using machinery without proper authorisation.
   j. Performing a task without using all proper safety equipment and precautions.

Unsafe Conditions

6. Unsafe conditions are those which could result in an accident or injury. Every individual has a legal responsibility to correct or report unsafe conditions, such as:

a. Untidy workshops.
b. Unguarded machinery.
c. Wet or slippery floors.
d. Inadequate lighting for a particular task.
e. Badly maintained hand tools.
f. Incorrect storage of flammable liquids.
g. Electrical equipment with damaged insulation or cords.

Results of Accidents

7. Accidents can result in one or more of the following:

a. Death or injury.
b. Pain and inconvenience.
c. Loss of production.
d. Loss or earnings.
e. Damage to machinery.
f. Damage to tools and equipment.
g. Loss of employment opportunities.
h. A financial burden on individuals or the community.

Main Responsibilities of Others

8. Although the primary responsibility for safety rests with the individual, others have a responsibility also, including:

a. **Government agencies**. They are responsible for making laws and standards intended to reduce accidents. They are also responsible for enforcing safety laws.

b. **Employers**. They are responsible for supplying the necessary safety equipment for use by employees and ensuring that company policy requires that proper safety equipment is used at all times.

c. **Industry**. Specific industry groups have a responsibility to ensure that aspects of the industry operate within agreed safety limits.

d. **Trainers**. People involved in the training of individuals have a responsibility to ensure that the trainees are aware of and practice all appropriate safety requirements.

e. **Manufacturers**. They have a responsibility to ensure that the use of their equipment will not result in accidents or injury.

Causes of Personal Accidents

9. The most common causes of personal injuries in an industrial situation are a strain in handling (such as lifting incorrectly) and falls. About 28-30% of injuries occur due to strain in handling and about 20-25% are due to falls.

10. The risk of injury or damage to equipment can be reduced if individuals are thoroughly trained in safety aspects such as:

a. Danger areas and safe access ways.
b. Safe Methods of Working.
c. Safety Tag System.
d. Proper use of personal safety equipment.
e. Danger resulting from improper use of gear or equipment.
f. Hazards arising from worn or faulty equipment.
g. Hazards arising from others working above, below or nearby.
h. Hazards from mobile equipment.
i. Hazards from overhead cranes.
j. Storage and handling of flammable liquids.

Safe Behaviour

11. Examples of guidelines for safe behaviour in the workplace are:

a. Do not skylark in the work area.
b. Do not operate switches without proper authority.
c. Do not tamper with safety equipment such as fire extinguishers, warning signs, emergency stop buttons and machinery guards.
d. Take care when handling cotton waste - it can contain small pieces of sharp swarf.
e. Concentrate on the job at hand.
f. Take notice of safety signs.
g. Always use the correct danger tag procedures.
h. Do not run in workshops - particularly in confined spaces such as in corridors or on stairways.
i. Be conscious of the need for safety at all times.
j. Always use the appropriate personal safety equipment.
k. Do not interfere with electrical equipment without authority.

Safe Procedures

12. General procedures which will result in a safe work area in an electrical workshop environment include:

a. Keep work-benches tidy.
b. Store hand tools in an appropriate place when they are not in use.
c. Keep thoroughfares free from obstructions.
d. Do not leave off-cuts of material lying around.
e. If liquids are spilt on the floor, clean them up.
f. Do not use sawdust to soak up spilt liquids - it can create a fire hazard. Special absorbent granules are available for soaking up spilt liquids.
g. Do not allow tools or equipment to project beyond the edge of the work-bench.
h. Do not wipe dirty or oily hands on your clothing - use a cloth or an equivalent.
i. Do not throw oily rags into a general-purpose rubbish bin - they can catch fire by spontaneous combustion. Use special metal bins which are emptied regularly.
j. Do not leave the cord of an electric hand tool dangling over the front of a workbench.
k. Do not use machinery if the safety guard is missing or inadequate.
l. Do not store solvents or petrol in plastic containers - the liquid may dissolve the plastic.

Personal Safety Equipment

13. The main items of safety equipment designed for personal protection in an electrical workshop are:

a. Head Protection: Helmets, caps, berets.
b. Eye Protection: Safety glasses, face shields or goggles.
c. Face Protection: Transparent face shields.
d. Foot Protection: Safety shoes or boots
e. Ear Protection: Ear muffs, approved earplugs.
f. Lung Protection: Respirators, masks.
g. Hand Protection: Gloves, barrier cream
h. Body Protection: Overalls, aprons.

14. Special attention needs to be paid to safety requirements on a construction site because of the temporary nature of walking surfaces, material storage areas, construction aids etc. The safety items which should be worn on all construction sites are an approved safety helmet and safety boots or shoes. Other items such as eye protection, hearing protection and lung protection will be required for specific tasks.

Safe Use of Machinery

15 Electrical workshops are equipped with hand tools and small metal-working machines such as lathes, drilling machines, off-hand grinding machines, guillotines, welding equipment etc. The specific safety aspects of such equipment will be dealt with in detail at the relevant stage of this course, but general safety procedures include:

a. Do not remove the swarf with the fingers.
b. Ensure that the workpiece is securely clamped in position when metal is being removed.
c. Ensure that all guards are in good condition and the correct position.
d. When using cutting tools, keep the cutting edge pointing away from you.
e. Avoid inhaling vapours from liquids such as solvents, thinners, petrol etc.
f. Do not use a machine unless you have been instructed in its use.
g. Ask for assistance if you are unsure of any procedure.
h. When working on equipment that may roll (such as an electric motor), make sure it is supported so that it can not roll off the bench.
i. Do not wear thongs in the workplace.
j. Wear suitable clothing which covers the upper part of the body - not singlets or tank-tops.
k. Do not wear rings, wristwatches or other personal items that may get caught in machinery.
l. Consider the safety of others in the immediate vicinity.
m. Long hair needs to be restrained with a hair net.

Power Tools

16 The following precautions should be taken when using electric power tools:

a. Do not use a portable electrical machine that has a frayed cord - label the tool and report it to your supervisor.
b. Do not use an electrical tool that has a broken outer casing - live internal parts may be exposed.
c. Do not suspend an electrical power tool by its cord.
d. Do not overload power tools.
e. Keep a firm grip on power tools when they are in use.
f. Make sure the workpiece is fixed so that it can not move.
g. Do not use an electrical tool that has been sprayed with water.
h. Unplug a power tool when you have finished using it.
i. Make sure that there is nothing obstructing cooling holes in portable power tools.

j. Take care when operating variable speed power tools at low speeds for long periods - they can overheat and burn out.
k. Do not put a power tool down until it has stopped turning.
l. Check the voltage rating of a power tool before plugging it in.
m. Flexible extension cords used on construction sites must be inspected and tagged by a licensed electrician.

17. Double insulated electrical power tools are identified with the international symbol for double insulation - one square inside another. Double insulated power tools must not have the exposed metal earthed (because it creates an 'earthed situation').

General Electrical Safety

18. The following general guidelines should be followed to maintain electrical safety in an industrial situation:

a. Report any defective electrical equipment immediately.
b. Protect extension leads and power cables so that they cannot be damaged by crushing, by, for example, wheeled trolleys.
c. If you feel any kind of electric shock, switch the machine off, tag it and report it immediately.
d. Beware of live overhead conductors when handling long metallic pipes or bars.
e. Do not use water or water-based extinguishers to combat an electrical fire.
f. Do not use an extension cord while it is wound on a drum - it can easily overheat.
g. Switch electrical machinery off when it is not in use.

Observing Safety Requirements

19. Notwithstanding the responsibilities of others, safety precautions, safety equipment and procedures are of little value if the individual in the workplace ignores them or is unaware of them. You are legally responsible for your safety and the safety of others. If you fail to observe proper safety procedures, or if you fail to take action to report or correct an unsafe situation you may be liable to prosecution - even if you are not directly involved in the work being done.

Risk Management

20. Electricity is generally regarded as an indispensable part of modern domestic industrial and commercial life. It is around us all the time in some form. In most cases, electricity cannot be seen directly, but its effects can be seen in the form of lighting devices, heating devices, electric motors and so on. The electricity produced by supply authorities or network operators is at voltages high enough to cause death by electrocution if a person or animal comes in contact with a live part under some circumstances.

21. Electricity can also cause fire, explosions or damage to sensitive equipment if the potential hazards are not recognised and managed. All electrical workers have a legal responsibility to protect themselves and others from the risks associated with the potentially hazardous effects of electricity in the workplace.

22. The most common situations in which there is a risk of electrocution, fire or damage to property are:

a. A person or animal coming in direct contact with a live part.
b. A person coming in contact with a part that has become life as a result of an electrical fault condition (indirect contact).
c. A person coming too close to a high voltage part.
d. A person handling a sensitive electronic component without observing adequate precautions.

e. Allowing a spark to occur in a flammable or explosive environment.
f. Allowing electrical devices to operate under conditions outside their designed capabilities.
g. Switching an electrical device OFF when it is in a condition where stored energy cannot be released normally.
h. Disabling or bypassing electrical protective equipment.
i. Failing to use the correct testing and isolation procedures before working on an electrical component.

23. In general, to work on or near electrical equipment it is first necessary to determine whether it is safe to do so. If a risk assessment has indicated that risks cannot be sufficiently controlled or eliminated to enable the work to be done safely on or near electrical equipment, then work must not proceed.

Principles of Risk Management

24. The general principles for the management of risks associated with the use of electricity are:

a. Identify the hazard.
b. Assess and prioritise the risks.
c. Apply control measures to the identified risks.

Hazard Identification

25. For this module hazards in the workplace can be classified in general as either electrical or non-electrical. Electrical hazards are those that can result in:

a. Electrocution (by direct contact, indirect contact under fault conditions, or coming too close to high voltage equipment.
b. Fire, explosions, flashes or burns.
c. Damage to property due to the effects of current flow or the unintended interruption to current flow.

26. AS/NZS 4836:2011 identifies several typical sources of electric shock that may be encountered in the workplace (see Clause 2.3.1) viz:

a. Voltages between phases and between phases and neutral.
b. Voltages between phases and earth.
c. Voltages across open switch contacts.
d. Voltages across undischarged capacitors.
e. Voltages on disconnected conductors (particularly neutrals).
f. Voltages caused by static electricity.
g. The rise in earth potential in MEN systems.
h. Induced voltages.
i. The voltage across secondary terminals of transformers, including current transformers.
j. Voltages between different earthing systems.
k. Incorrect wiring connections.
l. Faulty equipment.
m. Voltages from other sources.

27. Non-electrical hazards are any other situation where failure to use appropriate procedures or equipment can result in injury to people or animals, or property damage. Typical general types of hazards are listed below under six general headings:

Physical

Machines
Dust
Flammable materials
Heat and cold
Noise
Vibration
Inadequate lighting
Working space
Vehicles
Adequate personal protection
Ladders
Scaffolding

Chemical

Gases
Fumes
Solvents
Chemicals
Liquids

Ergonomic

Tool design
Equipment design
Workstation design
Materials handling techniques
Repetitive tasks

Radiation

Ultra-violet radiation (welding)
Microwaves
Electro-magnetic radiation
X-rays
Infra-red radiation

Psychological

Workload
Shiftwork
Harassment
Discrimination
Dangerous environment
Low-level noise
Mental stress

Biological

Bacteria
Sources of infection

28. Several other factors can increase the hazard in specific circumstances, such as:

    a. Cramped working conditions.
    b. Confined spaces.
    c. Multiple sources of supply.
    d. Damp situations.
    e. Heat.
    f. Height.
    g. Operational pressures to carry out work or restore electricity supply.
    h. Unstable work area.
    i. Conductors or cables or equipment under a tension likely to fall.

Assessing and Prioritizing the Risks

29. All work needs to be planned and organised to minimise the risks associated with that work. The process of comparing the level of risk found during the risk analysis process with previously established risk criteria to decide whether the risk can be accepted is known as a 'risk assessment'.

30. The processes of risk identification and risk assessment need to involve all workers involved in performing the task. If risks that may have the potential to cause harm or damage are found to exist, the risks must be prioritized and appropriate control measures implemented to reduce the risks to an acceptable level.

Risk Control

31. Risk control is the process of considering each hazard in turn and deciding what action is required to reduce its potential effects to an acceptable level. The sequence of events to control the hazard (known as the 'hierarchy of controls') is as follows:

    a. Eliminate the hazard, which is always the priority, e.g. by rescheduling work to a time when it can be done de-energised).
    b. Separate the worker from the hazard, e.g. by distance or barriers.
    c. Reduce the level of hazard, e.g. by the use of safety equipment, personal protective equipment (PPE), a safety observer or by training workers in working in the presence of a hazard.

32. Working on or near exposed energised conductors shall be considered only when an adequate risk assessment indicates that:

    a. there is no suitable alternative and
    b. the preparations specified in Clause 3.2.5 of AS/NZS 4836 have been carried out.

33. Electrical safety depends upon:

    a. Appropriate job planning
    b. Correct testing and isolation procedures and techniques.
    c. The use of tools, test instruments, personal protective equipment (PPE) and machinery that are fit for the purpose.
    d. The work is being carried out by competent people.

34. All electrical conductors, including earthing conductors, must be treated as energised until proven de-energised. All devices used to test for the de-energised condition must be checked for correct operation immediately before and after they are used.

Wiring Rules

35. Clause 1.5 of the Wiring Rules (AS/NZS 3000:2007) provides information on how electrical installations must be arranged to protect users of electrical devices from the potentially hazardous effects of electricity under normal conditions.

Isolation of a Supply

36. The five main steps in the process of isolating and making safe in preparation for working on de-energised equipment are Identity. Isolate. Test. Tag. Lock-off.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-3	Version 4 2021

Industrial Safety

1. Who is primarily responsible for the safety of the individual in a workshop or on a construction site?

2. Who is primarily responsible for ensuring that an employee uses the appropriate safety equipment in a workshop or on a construction site?

3. What two items of safety equipment should always be worn on construction sites?

4. What item of safety equipment should always be worn when working on or around machines designed to remove material (such as drills, lathes, grinders and chasing saws)?

5. What is the internationally recognised symbol that means 'double insulated - do not earth'?

6. Why is it unsafe to use a 240-volt portable electric power tool if it has a frayed or damaged flexible cord?

7. What action should always be taken before operating unfamiliar equipment?

8. Name one item of safety equipment that can be worn to protect the following:

   a. The head
   b. The eyes
   c. The ears
   d. The lungs
   e. The hands
   f. The feet
   g. The trunk of the body.

9. What is the first thing which must be done before commencing work on or near any electrical equipment?

10. If a risk assessment indicates that risks cannot be eliminated or sufficiently controlled to enable work to be done safely on or near energised equipment, can the work proceed?

11. Before any work is done on or near energised electrical equipment a risk assessment must be carried out at the worksite to assess all risks that might have the potential to cause harm or damage. Who is required to be involved in the task of risk identification and assessment?

12. What is the main purpose of adopting a planned risk management process on an industrial worksite?

13. What is meant by the term ‘hierarchy of controls’ when applied to risk control?

14. List the five main steps in the process of isolating and making safe in preparation for working on de-energised equipment.

ANSWERS PAGE 207

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary 1-4	Version 4.1 2021

1.4 - Lifting, Ladders and Special Situations

The Kinetic Method

1. The two most common causes of personal injury in an industrial situation are a strain in handling (e.g. lifting injuries) and falls.

2. The risk of injury as a result of strain in handling can be minimised by observing the following precautions (known as the Kinetic Method):

a. Keep the back straight when lifting.
b. Lift with the legs, not with the back.
c. Grip the object firmly at diagonally opposite points.
d. Grip the object with the palms of the hands - not the fingers.
e. Do not grip a part of the object that can or may move (such as the
1. shaft of an electric motor).
f. Keep the head erect with the chin in.
g. Hold the object and your arms close to the body.
h. Position your feet as close as possible to the object being lifted.
i. Get help if the object is too heavy to lift comfortably.
j. Do not twist the trunk of the body while supporting a heavyweight - move the feet.
k. Plan the lift.

Lifting Aids

3. A mechanical lifting aid should be used if the object to be lifted is too heavy or awkward to lift unaided. Typical lifting aids include:

a. Overhead cranes or hoists.
b. Transportable hydraulic hoists.
c. Suction grips, tongs or lifting hooks for handling sheet materials.
d. Chain block and tackle.
e. Forklift truck.

Ladders

4. Ladders are used to perform small tasks above floor or ground level. For prolonged work above floor level, a mobile platform or scaffold should be used.

5. The main types of ladder used for electrical work are:

a. Single or pole ladders (without wire reinforcing).
b. Step ladders (made from wood or fibreglass).
c. Extension ladders (made from wood or fibreglass).

6. The following procedures should be followed when using or storing ladders:

a. Select the type of ladder appropriate to the task.
b. Make sure that the ladder is in serviceable condition.
c. Do not use metal ladders or wooden ladders with wire reinforcing for electrical work.
d. Do not stand on rungs or steps less than one metre from the top of a ladder.
e. Do not store ladders in such a way that they may bend or warp.
f. When 'footing' a ladder, put one foot on the bottom rung, grip both stiles, watch the climber. Footing a ladder prevents the base from slipping out and the ladder from slipping sideways.
g. When transporting ladders, hold them at the point of balance.
h. When erecting a pole or extension ladder, the angle of the ladder should be such that the base of the ladder is one unit out for every four units up.
i. The base of a ladder must be positioned and secured so that it can not move.
j. Soft-soled shoes should not be worn when working on pole or extension ladders - the round rungs can result in dangerous foot cramps.
k. The top of a ladder must be secured so that it can not move.
l. Extension ladders must be used the right way up and the right way round.
m. Do not stretch sideways when on a ladder - climb down and re-position the ladder.
n. Do not use a ladder that has oil, grease or mud on the rungs.
o. If several tools are required while working on a ladder they should be raised in a suitable pouch or haversack - do not climb a ladder using one hand.
p. When erecting a ladder, check for overhead obstructions before raising it.
q. Two people are required to erect a long or heavy ladder.
r. If a ladder is to be used in front of a door, make sure that the door is locked, closed or blocked open.
s. If a ladder is to be used against a pole the top of the ladder should be fixed in position with a suitable strap, chain or rope.
t. Do not leave erected ladders unattended unless they are secured at the top and bottom.
u. The legs of a step ladder must be fully extended on a level surface before the ladder is climbed.
v. Do not use bricks or small blocks under the stiles of a ladder to compensate for uneven ground.

Body Belts

7. Body belts should be worn when working from single pole or extension ladders. Body belts must be made from synthetic webbing (not leather), and they should be of a type approved by Australian Standards. A body belt should be checked daily for damaged stitching, damage to the fabric of the belt, wear or damage to the buckles. A body belt should be tested at ground level each day it is used.

Mobile Platforms and Trestles

8. The following precautions should be taken when working on mobile platforms:

a. Make sure that adequate guardrails and toe boards are fitted to the platform.
b. Ensure that the wheels are locked in position before mounting the platform.
c. Never move a mobile platform if there is anyone on it.
d. Position a mobile platform so that the work can be done without reaching over the open sides.
e. The height of a mobile platform should be no more than three times the smallest base dimension.
f. Get help when moving a mobile platform into position.
g. When working on a mobile platform, consider the safety of others who may be working below you.

9. The following precautions should be taken when working on scaffolding erected on trestles:

a. The working surface of a scaffold should be at least 450 mm wide.
b. The planks which form part of the scaffold should not project less than 150 or more than 230 mm beyond the supports.
c. The planks of the scaffold should be positioned so that they touch each other.
d. All planks and trestles should be checked to see that they are sound before using the scaffold.
e. The feet of a trestle scaffold must be on a firm, flat surface.

Pits or Excavations

10. The following precautions should be taken when working in pits or excavations:

a. All openings to the pit or excavation must be guarded with barriers so that other people can not fall into them.
b. Warning signs should be displayed at open pits or excavations.
c. Never jump across an open pit - walk around it.
d. Do not enter a pit or excavation unless you are authorised to do so.
e. Use a ladder or steps to enter a pit - do not jump into it.
f. Ensure that there is adequate ventilation when working in a pit or excavation.
g. Ensure that the walls of a pit or excavation are adequately supported.
h. If the pit or excavation is more than 1.2 metres deep a person should be stationed at ground level in case an accident occurs.
i. Do not work in a pit if dangerous gases or fumes are present.

Confined Spaces

11. The following precautions should be taken when working in confined spaces:

a. Never enter a confined space unless you are authorised to do so.
b. Plan your exit so that you can get out quickly if you begin to feel dizziness, nausea or a headache.
c. Do not enter a confined space without an appropriate lifeline.
d. Do not enter a confined space unless there is another person outside.
e. Wear a respirator if there is any possibility of fumes being present in the confined space.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-4	Version 4 2021

Lifting, Ladders and Special Situations

1. What are the two main causes of ladder accidents?

2. What type of ladder should be used for heights up to about 2 metres?

3. What type of ladder should be used for heights over about 2 metres?

4. List FIVE safety aspects that must be checked before a pole ladder is used.

5. What are the THREE main factors which must be considered when selecting a ladder for a particular task?

6. A 4-metre pole ladder is to be used up against a vertical brick wall. What distance should there be between the base of the wall and the base of the ladder?

7. A pole ladder is to be used to climb onto a rigid platform. How many rungs of the ladder should extend above the platform?

8. List two possible methods of securing the TOP of a pole ladder.

9. What two unsafe pole ladder movements can usually be prevented by 'footing' the ladder?

10. Describe the position which should be adopted by a person who is 'footing' a pole ladder.

11. How should tools be taken aloft when working on a ladder?

12. List THREE aspects that must be considered or inspected on a STEP ladder before it is climbed.

13. Is it safe to perform a task while standing on the top rung of a step ladder?

14. Supply the missing words in the following statement:

    An extension ladder must always be used the right way .....?..... and the right way.....?......

15. What common type of ladder is unsuitable for electrical work?

16. What is the main disadvantage of using soft-soled shoes (such as sandshoes) when using a pole ladder or an extension ladder?

17. Why is it dangerous to use a ladder which has oil, grease or mud on the rungs?

18. What important safety precautions should always be taken when lifting any object from floor level?

ANSWERS PAGE 208

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary 1-5	Version 4.1 2021

1.5 - Electrical Safety in Installations

Active Safety Measures

1. Do not begin any electrical work until the electricity supply has been disconnected. Always treat electrical devices as ALIVE until YOU have checked to see that they are dead. Never ASSUME that a wire is dead. The procedure must be ISOLATE, TAG, CHECK for zero volts.

2. When checking to see if any electrical device or terminal is alive, always check the checking instrument BEFORE and AFTER the check. CHECK, PROVE, CHECK.

3. Always switch the machine off and REMOVE THE PLUG from the socket before working on portable electrical appliances.

4. Do not poke metallic objects into electrical tools or machines.

5. Do not switch an electrical machine on if it has been sprayed with water. Tap water is a good conductor, so water and electricity are always a potentially dangerous combination.

6. In installations that have fuses, remove the appropriate fuses and take them with you before working on any part of the circuit.

7. When removing the fuses for a circuit, make sure that they are the CORRECT fuses for the circuit you are going to work on.

8. When you remove fuses from a circuit, attach a RED danger tag in an easily visible position on or near the fuse base.

9. Treat earth wires (green/yellow) or neutral wires (BLACK for fixed wiring or LIGHT BLUE for flexible cord) as being alive until YOU have checked to see that they are dead.

10. When you send someone else to remove fuses or switch a circuit breaker off, always assume that they have removed the WRONG fuses until you have checked for zero volts.

11. Take extra care when standing on metal, concrete or damp floors.

12. Remember that one thin strand of a flexible cord is just as dangerous as a heavy piece of wire.

13. If you go to work on a circuit and find the fuse or switch already has a danger tag fitted, you must still put your RED danger tag on the fuse or switch.

14. At high voltages, a person can be electrocuted by coming CLOSE to a live terminal (without actually touching it).

15. Keep metal and metal impregnated objects well away from living parts.

16. Never switch a single insulated machine on unless it is effectively earthed.

17. Report unsafe conditions to your supervisor for corrective action.

18. Never assume that a machine has been switched off if it is not operating - it could be alive but faulty.

19. Never work on live equipment if it can be avoided. If it cannot be avoided do not start work unless another person is present, and use the appropriate safety equipment to avoid electric shock. Apprentices are not permitted to work on live equipment unless they are in their fourth or final year; fourth or final year apprentices require CONSTANT supervision on live work (including live testing).

20. Switch off, isolate and tag electrical equipment BEFORE starting work or removing any covers.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-5	Version 4 2021

Electrical Safety in Installations

1. What fundamental safety precaution must be taken before working on an electrical circuit or device which is presumed to be 'dead'?

2. Before commencing work on a 230/240-volt portable appliance it is essential to switch it off and remove the plug from the outlet. Why is it essential to remove the plug from the outlet as well as switch it off?

3. Is it safe to assume that a permanently connected electrical device is safe to work on if it is not operating?

4. What five steps must be taken before working on any equipment which is connected to fixed wiring?

5. What two essential precautions must be taken if it is necessary to work on a piece of equipment while it is alive?

ANSWERS PAGE 209

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary 1-6	Version 4.1 2021

1.6 - Effects of Electric Shock

1. Electric shock can be, and often is, fatal. Electrical workers have a direct responsibility to protect themselves and the public from exposure to electric shock. Work should not begin on any electrical device or circuit until a suitable measuring device has been used to confirm that the circuit is dead. Although voltages less than about 30 volts are usually considered to be harmless, unintended contact between parts can result in short circuits, electrical flashes, burns or damage to the equipment.

2. A small electric shock can cause a mild tingling sensation in the muscles of the arm, but a severe shock causes a sudden contraction of the heart muscles that can stun the victim and may have one or more of the following effects:

   a. The victim stops breathing.

   b. The victim's heart stops or quivers rapidly without pumping blood - a condition known as ventricular fibrillation.

   c. The victim suffers severe burns.

   d. The victim suffers a traumatic shock to the nervous system.

   e. The victim suffers muscular paralysis and may be unable to release his/her grip on a live machine.

Factors

3. The factors which affect the seriousness of electrical shock are:

   a. The amount of current passing through the body.

   b. The path of the current through the body.

   c. The voltage of the circuit.

   d. The duration of contact with the live part.

   e. The resistance of the body at the time of contact.

   f. The surface area of the skin in contact with the live component.

   g. The period of the cardiac cycle during which the shock occurs.

   h. The individual - some people are affected more than others.

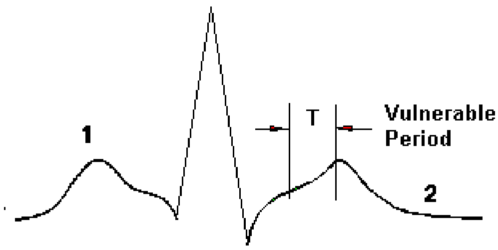
4. It is not possible to define precisely the effects of a given current on the body, but the general effects of alternating current are shown in Figure 1.

```
 Current in
  Amperes
         |
   0.5   |-    Severe burns
         |
         |
         |
         |     Breathing stops
   0.2   |-    Death usually occurs
         |
   0.1   | - - - - - - - - - - - - - - - - - -
 (100 mA)|     Extreme breathing difficulties
         |     Breathing upset and laboured
         |
         |     Severe shock
   0.05  |-    Muscular paralysis
  (50 mA)|     Can not let go
         |
         |
         |     Painful
   0.01  | - - - - - - - - - - - - - - - - - -
  (10 mA)|
         |     Mild sensation
         |
         |     Threshold of sensation
         |
  0.001  +-----------------------------------------
  (1 mA)
```

Figure 1 - General effects of electric shock

The Cardiac Cycle

5. The small electrical impulses which stimulate normal muscular contraction of the heart to follow a regular pattern can be represented on a graph known as the 'Cardiac Cycle', as shown in Figure 2.




```
  T    - The vulnerable period

1 - 2  - One normal cardiac
         period (heartbeat)
```

Figure 2 - The cardiac cycle

6. It is thought that there is a specific period during the cardiac cycle when the heart is most likely to be affected by an electric shock. This period is known as the 'vulnerable period' as indicated in Figure 2. If a person receives an electric shock during the vulnerable period, the probability that the heart will go into ventricular fibrillation is increased.

7. The existence of a period of higher vulnerability may explain why some people may suffer no long-term effects from an electric shock, while others receive a shock under similar conditions and fail to recover.

Burns

8. The passage of electric current through the human body can result in severe burning of body tissue. The effects of electrical burns often contribute more to the cause of death than the electric shock itself.

General

9. Research indicates that most fatal shocks are caused by low currents of short duration. There is no such thing as a safe electric shock, therefore every possible precaution must be taken to prevent you or any other person from coming in contact with a live component.

10. A significant number of electrical fatalities in Australia are a direct result of incorrectly wired plug tops.

11. Electrical accidents can be prevented by adopting safe working practices. One of the guiding principles which must be adopted by any person working on electrical equipment is TEST BEFORE YOU TOUCH.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-6	Version 4 2021

Effects of Electric Shock

1. List four of the effects of electric shock on the human body.

2. List four factors that affect the seriousness of an electric shock.

3. What potentially fatal effect can an electric shock have on the human body, apart from the effects of the electric shock itself?

4. How can you account for the fact that some people survive an electric shock from a short duration high voltage supply while others do not recover after contact with a lower voltage?

5. What are five actions that should be taken to administer first-aid to a conscious person who has just suffered a severe electric shock?

6. What condition is indicated if a person has pale and clammy skin, or a feeble and rapid pulse, following an accidental electric shock?

7. What are five actions that should be taken to administer first-aid to an UNCONSCIOUS person who has just suffered a severe electric shock, if the person is breathing and has a detectable pulse?

ANSWERS PAGE 210

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary 1-7	Version 4.1 2021

1.7 - Rescue and Resuscitation

Rescue and Resuscitation

1. Electrical accidents can cause burns, falls and electrical shock. Any one of these will produce various symptoms in the casualty who could be suffering from any one, or a combination of all these effects. It is therefore important to be able to distinguish between the various symptoms.

2. Although delay in rescue and resuscitation may prove fatal, electric shock does not kill at once, but it may stun the person, restricting or stopping breathing and affecting the heart.

3. The MOST important aspects to look for in electrical accidents are whether the casualty's breathing and/or heartbeat have stopped, as these two must be restored immediately.

4. When faced with the task of helping a casualty of an electrical accident, act quickly, SAFELY and in the following order:

5. MAKE IT SAFE for both the rescuer and casualty. Switch off the power supply to the electrical circuit, or, if this is not possible, remove the casualty from contact using any INSULATING material.

6. NEVER ASSUME THAT THE CASUALTY IS NOT STILL IN CONTACT WITH THE ELECTRICAL SOURCE UNTIL YOU HAVE CHECKED.

7. Once clear and safe to do so, apply first aid as dictated by the casualty's symptoms, carry out essential treatment e.g. clear airway -carry out resuscitation - stop bleeding. Fractures should be left until breathing and circulation have been restored.

8 Remember that until the victim is released from the shock source, the victim’s body is at the same potential as the voltage source.

9. Typical essentials of resuscitation - REMEMBER the D-R-S-A-B-C-D for treatment.

D	DANGER	Remove any source of danger.
R	RESPONSE	Check for a response.
S	SEND	Call for an ambulance dial 000 or mobiles 112
A	AIRWAY	Clear it.
B	BREATHING	Check for 2 breaths within 10 seconds.
C	CPR	Apply CPR until Medical aid arrives.
D	DEFIBRILLATOR	Attach a defibrillator (follow prompts)

Then attend to bleeding or other injuries.

9. A typical process for the management of an unconscious, non-breathing casualty with no signs of life is as follows:

Cardio Pulmonary Resuscitation (CPR)

	Check for danger
	Check for response
NO RESPONSE	Call for an ambulance and send for a defibrillator
CHECK AIRWAY	Look in mouth for foreign materials
NO FOREIGN MATERIAL FOUND	Leave on back
	Open airway - jaw lift, head tilt *Note for infants: Lift jaw and minimal head tilt to open airway*
	Check breathing for up to 10 seconds – 2 breaths Look - Listen - Feel
NOT BREATHING	Commence CPR Locate site for compressions - the lower half of breastbone in the centre of the chest
	Perform 30 compressions (at almost 2 compressions a second).- 1/3rd of chest depth.
	Give 2 breaths approximately 1 second for each and re-commence compressions within 5 seconds
	30 compressions and 2 breaths Complete approximately 5 sets of 30: 2 in 2 minutes
SIGNS OF LIFE RETURN	Check signs of life for up to 10 seconds – 2 breaths
SIGNS OF LIFE PRESENT	Place in Recovery Position and monitor airway, breathing and signs of life

10. The CPR process should be continued until medical help takes over the responsibility or the casualty responds to treatment.

11. Training in this process must be provided by a suitably qualified person.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-7	Version 4 2021

Rescue and Resuscitation

1. Could a rescuer receive an electric shock if he/she touches the SKIN of a person who is receiving a shock?

2. Is damp wood a suitable material for pushing an electric shock victim off a live component?

3. What three words are known as the A-B-C of artificial resuscitation?

4. Is it always necessary to apply mouth to mouth resuscitation AND external heart compression to an electric shock victim?

5. If mouth to mouth resuscitation and external cardiac compression is being administered to an adult by ONE operator, what is the recommended ratio of lung inflations to chest compressions?

6. How far should an adult's chest be compressed when administering external heart compression?

7. When should the process of administering mouth to mouth resuscitation be discontinued?

8. What is the first thing you should do if you see a person receiving an electric shock?

ANSWERS PAGE 211

1.8 - First Aid Procedures

1. Minor cuts and bruises must be treated no matter how minor they appear to be. Any injury can become infected and turn septic, if not treated promptly.

2. REMEMBER tetanus is ever-present and can cause death. All tradespeople and apprentices are well-advised to protect themselves against tetanus by having a simple injection from a medical practitioner.

3. Always report and record any injury, no matter how minor it seems. Any injury can become infected and turn septic if not treated promptly.

Minor Cuts and Bruises

4. Treat minor cuts and bruises as follows:-

   a. Let slight or moderate cuts bleed freely for about a minute to clear out possible causes of infection.

   b. Clean with the soft clean material.

   c. Apply antiseptic, sterile gauze dressing and bandage, or plaster bandage (Band-Aid) for small cuts.

   d. Seek medical treatment for all deep cuts.

   e. Severe bruising (which is bleeding under the skin) requires medical treatment with the least possible delay.

Nose Bleed

5. Nosebleed is best treated in the following way:

   a. Sit the casualty in a chair or on the floor with head bent slightly forward.

   b. Do not let the casualty blow his/her nose.

   c. Pinch, or have the casualty pinch their nose firmly at the junction of bone and cartilage.

   d. If bleeding does not stop within 5 to 10 minutes, seek medical attention.

6. Severe bleeding, in general, requires direct pressure to be applied to the wound. In cases of severe bleeding medical attention must be sought immediately. In the meantime the following treatment should be carried out:

   a. Expose the whole wound.

   b. Press over the wound with your hand, or squeeze the edges of the wound together. If there is time to cover the wound with a clean handkerchief or dressing before applying pressure.

   c. Maintain pressure over the wound by a THICK pad, bandaged in place. The pad must be large enough to cover the whole wound, and the entire pad must be covered by a bandage. Elevate the wound if possible.

   d. If the casualty complains of numbness, tingling, or pain in the bandaged limb, the bandage is too tight and should be slackened off a little.

   e. If bleeding continues, apply another pad and bandage, but DO NOT REMOVE the first one.

   f. If a piece of foreign material is lodged in the wound, or if something is protruding from the wound, DO NOT ATTEMPT TO REMOVE IT. In such cases, pressure can still be applied to the edges by placing a circular pad around the wound and bandaging it into position. Use this method where broken bones protrude from a wound.

Burns and Scalds

7. Burns and scalds require immediate treatment by following the three "C's": C - Cool C - Cover C - Carry

8. Arrange for the immediate medical treatment depending on the severity of the case and apply first aid as follows:

   a. COOL burns by holding them under clean cold running water or pouring cold water over the burned area. Care should be taken not to over-cool the casualty and cause shock. (Chemical burns should also be treated by flooding them with water.)

   b. DO NOT tear or pull clothing or other matter stuck to the burns.

   c. COVER with a sterile dry bandage (if available) otherwise cover with a clean sheet, clothing, towel or even clean plain paper.

   d. DO NOT touch burned areas where severe skin blistering or seared flesh is evident. DO NOT break blisters.

   e. CARRY (transport) the casualty to medical treatment in all but minor burns cases.

Eye Injuries

9. Eye injuries should only be treated by a medical practitioner but the following first aid can be carried out :

   a. Have the casualty hold the eye still. Never allow the casualty to rub an eye that has a foreign body in it.

   b. NEVER touch the eye surface with ANYTHING.

   c. Arrange for medical attention.

   d. Loosely bandage BOTH eyes if the casualty agrees.

   e. Guide the casualty to where he/she can receive medical attention.

Traumatic Shock

10. Shock occurs after almost every accident or injury. The casualty may be pale and have clammy skin or a feeble and rapid pulse. The casualty may even be unconscious. The following steps should be taken:

   a. Put the patient at rest. Comfort and re-assure a conscious casualty or place an unconscious casualty in the COMA or recovery position after all checks and first aid have been carried out.

   b. Keep patient warm and quiet.

   c. Loosen tight clothing.

   d. Keep casualty calm and confident of receiving help quickly.

Loss of Consciousness

11. The general first aid treatment for a person who has lost consciousness is:

   a. Ensure an abundant supply of fresh air and place in the coma or recovery position

   b. Loosen tight clothing.

   c. Cover the casualty but do not apply heat.

   d. Do not leave the casualty until help arrives.

   e. Do NOT attempt to give the casualty food or fluids.

Emergency Calls

12. Dial 000 (112 mobile phones) for AMBULANCE, POLICE or the FIRE BRIGADE, or 13 11 26 for the Poison Information Centre in W.A.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-8	Version 4 2021

First Aid Procedures

1. What is the initial first aid treatment for a nosebleed?
2. What is the general first aid treatment required to stop bleeding from an open wound?
3. What condition is indicated if an accident victim has pale and clammy skin together with a feeble and rapid pulse?
4. What is the first aid treatment for a person who is suffering from shock (not an electric shock)?
5. What is the first aid treatment for a person who has been overcome by gas or fumes, but is still conscious?
6. What mobile telephone number can be used to call an ambulance in Perth?
7. Why is it essential to report all injuries, no matter how minor they may seem?
8. Why is it undesirable to induce vomiting in a victim who has accidentally swallowed petrol, acids or alkalis?
9. What serious disease can be contracted through small skin punctures, scratches, abrasions and lacerations (cuts)?
10. What is the recommended first aid treatment for burns and scalds?
11. What is the immediate first aid treatment if acid is splashed in a person's eyes?
12. What part of the body can be permanently damaged within 4 seconds if it comes in contact with the liquid hardener used with 'two-part' glues and fibreglass resins? What is the first aid treatment?
13. What is the first aid treatment for an injury that results in a foreign body being lodged in the victim's eye?
14. What immediate action is required in the event of an accident involving a moving machine?

ANSWERS PAGE 212

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary 1-9	Version 4.1 2021

1.9 - Fire and Chemical Hazards

1. Fire can only exist when three factors are present:

   a. Fuel
   b. Heat
   c. Oxygen

2. There are five general classifications for fires:

   a. Class A - Common combustible materials such as Wood, Cloth, Paper, Cardboard.

   b. Class B - Flammable liquids such as Petrol, Kerosene, Oil, Paint, Solvents

   c. Class C - Flammable Gas such as LP gas, Acetylene, Ammonia

   d. Class E - Electrical Fires, such as those in Electric motors, Switchboards, Cables

   e. Class F - Fires involving cooking oils and fats.

Fire Extinguishers

3. The following fire extinguishers are available:

Type	Method	Extinguisher	Suitable Colour
Class A	Cool	Water under pressure Foam	All RED, BLUE, OATMEAL, RED/YELLOW RED/BLACK
Class B	Smother	Foam Dry Powder Carbon Dioxide (CO_2)	BLUE, RED/YELLOW RED/WHITE RED/BLACK
Class C	Gas Off	Dry powder	RED/WHITE
Class E	Smother	Dry powder CO_2	RED/WHITE RED/BLACK, RED/YELLOW
Class F	Smother	Vaporising liquid	BLUE, OATMEAL, RED/BLACK, RED/WHITE

Combating Fires

4. The following points should be considered when combating fires:

a. The first thing to do is raise the alarm
b. Do not allow the fire to get between you and the exit.
c. Crawl through a smoke-filled room.
d. Do not open windows to let the smoke out.
e. Use a correct extinguisher.
f. Note the location of emergency exits.
g. Read the local fire evacuation procedures (beforehand).
h. Keep escape routes free from obstructions.
i. Do not return a used extinguisher to a fire point.
j. Evacuate the area if the fire can not be controlled.
k. Do not re-enter a burning building.

Fire Prevention

5. Fires can be prevented by controlling sources of heat, i.e.

a. Do not overload electrical appliances or circuits.
b. Do not tread on or wheel trolleys over electrical cables.
c. Do not use lead lights without a proper guard.
d. Position heaters where they can not be overturned.
e. Dispose of cigarette butts safely.

6. Fires can be prevented by controlling sources of fuel, i.e.

a. Keep flammable materials away from heating appliances.
b. Keep flammable materials away from hot objects.
c. Do not weld on or close to flammable materials.
d. Do not smoke near flammable gases or liquids.
e. Avoid dust hazards - many types of dust are flammable.
f. Clean up spilt liquids.
g. Keep flammable materials in closed metal containers.
h. Place oily rags in metal containers with sealing lids.
i. Do not use flammable liquids to light fires.
j. Take care when handling flammable liquids.

Chemical Hazards

7. Electrical workers can be exposed to many chemicals and gases in the workplace. It is convenient to classify chemicals in terms of their physical effects - for example, they can be flammable, corrosive, explosive, irritant or toxic. Toxic chemicals can be further classified as asphyxiants (causing difficulty in breathing) and anaesthetics (causing loss of feeling) or carcinogens (causing cancer in organisms).

8. Typical chemicals or gases that may be found in an electrical environment include:

a. Polychlorinated biphenyls (PCBs) in old metal cased capacitors or the liquid insulant in old large power transformers. This has been associated with cancer in animals and can cause skin and throat problems, eye irritation and headaches.

b. Resin soldering flux. In block form or resin-cored solder. Prolonged inhalation of resin fumes from the soldering process can cause respiratory irritation.

c. Ozone gas. Prolonged arcing of contacts in confined areas can result in respiratory irritation if the gas is inhaled.

d. Hydrogen gas. Hydrogen gas is given off by unsealed automotive lead-acid batteries when they are charging or discharging. Hydrogen gas is highly explosive.

e. Battery chemicals. The chemicals which are used as electrolytes in cells and batteries are usually corrosive.

f. Cleaning solvents. Liquid solvents used for cleaning electrical parts can cause skin irritations and dermatitis.

Materials Safety Data Sheets

9. A Material Safety Data Sheet (MSDS) is a detailed summary of the composition and characteristics of a material that could be hazardous; its purpose is to provide information relating to the potential hazard and how it should be handled. Material Safety Data Sheets are made available from manufacturers of potentially hazardous materials.

10. A typical MSDS contains information such as:

a. The product name.

b. Identification and physical data, such as other names, chemical composition, ingredients, uses and physical properties.

c. Health hazard information, including effects of exposure, first aid treatment, advice to doctors and toxicity.

d. Precautions for use, such as exposure limits, ventilation, personal protection and flammability.

e. Safe Handling information, such as storage and transport, action if spilt, disposal and fire/explosion hazards.

f. Other information and references that may be available relating to the material.

11. If you are required to use chemicals in the workplace, you should make sure that the MSDS is readily available, and you should take the time to read it BEFORE you use the chemical. In general, a wise precaution is to avoid contact with any liquid chemical as much as possible.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-9	Version 4 2021

Fire and Chemical Hazards

1. What three conditions must be present for a fire to occur?
2. What dangerous situation can occur if oily rags are stored in bins or the bottom of lockers for long periods?
3. Is it safe to store flammable liquids in plastic containers?
4. What is the FIRST thing you should do if you discover an unwanted fire?
5. What type of materials are classified as a CLASS A fire when they are burning?
6. What type of materials are classified as a CLASS B fire when they are burning?
7. What type of materials are classified as a CLASS C fire when they are burning?
8. What type of equipment is classified as a CLASS E fire when it is burning?
9. What type of materials are classified as a CLASS F fire when they are burning?
10. What is the extinguishing agent in fire extinguishers that have an 'ALL RED' container?
11. What is the extinguishing agent in fire extinguishers that have a RED container with a BLACK band?
12. What is the recommended method of moving through a smoke-filled room?
13. What type of extinguisher must never be used to combat an electrical fire?
14. Why is it dangerous to use water to combat burning liquids?
15. Is an extinguisher with a RED/YELLOW cylinder suitable for combating electrical fires?
16. What emergency mobile telephone number can be used to call the fire brigade in Perth?
17. Apart from the flame itself, what is the other potentially dangerous aspect of a fire?
18. If a fire breaks out, what check should be carried out before you decide to fight it?
19. What specific action should be taken to reduce the possibility of the spread of fire when you leave a burning room?
20. Which type of fire extinguisher can cause suffocation if used in confined spaces?
21. Why is it potentially dangerous to use a carbon dioxide fire extinguisher while gripping the discharge horn?
22. What is the extinguishing agent in a fire extinguisher that has a RED cylinder with a WHITE band?

23. What type of extinguisher should be used to combat a Class C fire?

24. List the two types of fire extinguishers that can safely be used to combat an electrical fire involving live equipment in an open area.

25. When it is required to use chemicals in the workplace, what is the written document that must be readily available?

ANSWERS PAGE 213

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 1	1-10	2021

1.10 - Danger Tag Procedures

1. A fundamental responsibility of all electrical workers is to ensure their safety, the safety of other workers in their vicinity, and the safety of the public. In the electrical industry, two basic tagging systems must be used to warn others that it is unsafe to operate a particular machine or device. These are:

a. **The Danger Tag**. A danger tag is mainly RED and contains the words "DANGER - DO NOT OPERATE THIS EQUIPMENT/SWITCH/VALVE", as shown in Figure 1.

Lecturer taken photo 19 Oct 2011

Figure 1. Danger Tag (RED)

Danger Tags

2. If you have a job to do and you think there is a possibility that you can be injured if someone turns on the electricity (or the faulty machine or a flow of steam, gas or liquid), then YOU must fasten a red DANGER TAG to the isolating switch, valve or equipment at the start of the relevant final subcircuit or equivalent.

3. Each tag you put on must clearly show your name, your department and the date.

4. Nobody must operate the danger tagged switch or control until the job is finished and the danger tags have been removed. Only the person who put on the danger tag is allowed to remove it. Should that person be unavailable for any reason, your organisation's safety policy details the procedure to be followed to have the tag removed. A typical safety policy could state that if the person who fitted the danger tag is unavailable, his foreman or supervisor may do so only if he has personally investigated the situation, and is satisfied that it is safe to remove it.

5. If you see that the use of a switch, a valve, a control or a piece of equipment could injure you or anybody else it is YOUR RESPONSIBILITY to secure a danger tag to the isolating control. If you do not have a danger tag, make up some temporary danger sign until you get a proper tag.

The Out of Service Tag. An out of service tag is mainly YELLOW and BLACK and contains the words "OUT OF SERVICE - NOT TO BE OPERATED", as shown in Figure 2.

Lecturer taken photo 19 Oct 2011

Figure 2. Out-of-Service Tag (Yellow and Black)

Points to Watch

6. a. Make sure that the switch, valve, control or equipment is the correct one to tag. If you have any doubts, ask your supervisor.

   b. Make sure that you leave the switch or control in the correct safe position.

   c. Some switches are not positive isolating switches. Switches such as the simple push-button type, emergency stop buttons, master control and control switches are not, and cannot be used as, isolating switches.

   d. Fasten the danger tag securely at the origin of the final subcircuit.

   e. When two or more people are working on the same job, each person must fasten their danger tag to the main isolating switch or control.

   f. The supervisor or person in charge must investigate the work area and fasten his danger tag to any point which, if operated, would be dangerous. The supervisor is then responsible for seeing that all personnel under his control have removed their danger tags and the job is safe before his tag is removed.

   g. If you go on a job and find a switch or control already danger tagged, you must still attach your danger tag.

7. If you come to the end of your shift and the equipment or machine is still unsafe, remove your danger tag and fit a yellow OUT OF SERVICE tag in its place.

Out of Service Tags

8. The yellow and black “OUT OF SERVICE” tags show which equipment or machinery is out of action for repairs or alterations, avoiding possible damage to the plant if someone happened to use the switch/equipment/valve etc. Equipment that has an Out-of-Service tag fitted must not be operated, except with the direct permission of the person in charge.

9. If machinery or equipment is faulty or damaged, and you can see that by using it more damage would occur, or could injure someone, you must fasten an Out of Service tag to it and inform your supervisor immediately. On no account must you leave the site without telling your supervisor what you have done.

10. Even if a piece of equipment or machinery is not itself faulty, it may be connected to something faulty, in which case you must fasten an Out of Service tag on BOTH items.

Extended Jobs

11. If faulty or incomplete equipment cannot be brought to full working order before the end of a shift, the person in charge of the job must fix an Out of Service tag on the main isolating switches or controls before the danger tags are removed. The supervisor and the supervisor of any other department concerned must then be informed of the condition in which the equipment is left.

12. When the servicing or installation is commenced, every man on the job must attach his danger tag. When the job is finished and the equipment is safe to operate, the supervisor must see that each person removes his danger tag and is safely clear, and finally remove the Out of Service tags.

Installation or Relocation of Equipment

13 When equipment or machinery is first installed, or when it is moved to another location, it must not be operated until it has been passed by a supervisor. The person who completes the installation of the equipment must attach an Out of Service tag to it and report to the supervisor that the installation of the equipment or machinery is complete and ready for inspection.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-10	Version 4 2021

Danger Tag Procedures

1. What are the two colours on a 'DANGER - DO NOT OPERATE' tag?
2. What are the two colours on an 'OUT OF SERVICE' tag?
3. Where must a 'DANGER - DO NOT OPERATE' tag be positioned?
4. Is it necessary to attach a 'DANGER - DO NOT OPERATE' tag if a similar tag has already been attached by another person?
5. What three items of information should be written on a danger tag before it is attached?
6. Who should remove a danger tag under normal working conditions?

ANSWERS PAGE 214

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 1	1-11	2021

1.11 - Isolation of Supplies

Plug-in Appliances

1. The procedure for isolating a single, two or three-phase appliance which is designed to operate via a plug top inserted into an appropriate socket outlet is as follows:

    a. Make sure that the appliance is switched off.

    b. Switch the switch off at the socket outlet.

    c. Remove the plug from the socket outlet.

Direct Connected Appliances

2. Directly connected appliances are those which are permanently connected to the fixed wiring in an installation.

3. Directly connected appliances are supplied from a switchboard that will have one or more fuses or air circuit breakers (ACB's) depending on whether the appliance is one, two or three-phase. In the case of two or three-phase appliances controlled from a circuit breaker, the circuit breaker will be a double or triple pole, with one operating lever or toggle.

4. Before attempting to isolate the appliance, it is necessary to establish whether it is one, two or three-phase so that the appropriate number of fuses can be located. The appliance nameplate is the usual source of relevant information.

5. Having established the number of phases the circuit can be traced back to the switchboard. The fuses or circuit breakers on the switchboard should be examined in conjunction with the switchboard legend to accurately locate those associated with the circuit to be isolated. Accurate identification of the required fuses or circuit breakers is essential. If, for example, you attempted to withdraw the wrong fuses you could:

    a. Cut the supply to another important machine.

    b. Draw an arc and burn yourself or suffer an eye injury.

    c. Leave the appliance you intend to work on alive, thus creating a dangerous electrical hazard.

6. If the circuit is protected by a circuit breaker it should be carefully examined to determine the off position. Most circuit breakers are the opposite of normal switch mechanisms - the OFF position is DOWN; a label should be visible on the circuit breaker indicating whether it is off or on.

Isolation

7. The procedure for isolating an appliance or machine consists of several basic operations:

   a. Identify the relevant device and switch it off. Lock it off with a padlock if possible.

   b. Isolate the supply by withdrawing the fuses or switching the circuit breaker to the off position.

   c. Attach your danger tag to the fuses or circuit breaker to warn others that the circuit must not be re-energised.

   d. Check your test instrument (usually a multimeter) on a known voltage source (240V), to see that it is working properly.

   e. Test for zero volts at the point at which you are to begin work. Test between all actives, from all actives to neutral, and from all actives to earth.

   f. Re-check your test instrument to see that it is still working properly on a known voltage source (240V).

   g. Double check all conductors using a phase pencil.

8. If the appliance is found to be alive after you have isolated the supply it means that something is wrong. Possible faults could be:

   a. The wrong isolating switch has been switched off.

   b. The wrong fuses have been removed or the wrong circuit breaker switched off.

   c. The wiring is faulty, damaged or incorrectly installed.

   d. The circuit is being fed from more than one source.

   e. Any combination of the faults listed above.

9. If it is necessary to leave conductors temporarily disconnected, tape them up or make them safe. If a circuit is not being used, the Wiring Rules require that the cables be disconnected from the mains - usually by disconnecting them at the circuit protection device.

Written Isolation Procedure

10. It is sometimes necessary to prepare a written isolation procedure, such as in cases where routine maintenance has to be done on a particular machine regularly. A typical scenario and written isolation procedure are given below:

Scenario

You have been asked to disconnect and remove a 415 volt 3 kW three-phase delta connected squirrel cage induction motor from a floor-mounted woodworking machine in a joinery factory.

The motor is wired on its final subcircuit and power is supplied from a circuit breaker on a sub-distribution board in the same part of the factory. The sub-distribution board is visible from the woodworking machine

A manually operated isolating switch is installed adjacent to the woodworking machine.

The cables to the motor are enclosed in a 300 mm length of flexible PVC conduit.

There are 10 other machines, 5 machine operators and 1 supervisor in the same general area.

Isolation Procedure

#	Action	
1	Advise the supervisor that power is to be disconnected and negotiate a convenient time.	
2	Identify the machine and switch it off at the isolating switch adjacent to it.	
3	Identify the relevant circuit on the sub-distribution board.	
4	Isolate the supply by switching the circuit breaker to the off position. Lock it in the OFF position.	
5	Attach a 'Danger Do Not Operate' danger tag to the identified circuit breaker to warn others that the circuit must not be re-energised. Write your name, the date and the time on the danger tag.	
6	Check the test instrument (usually a multimeter) to see that it is working properly on a known voltage source.	
7	Test for zero volts at the motor terminals. Test between all actives, from all actives to neutral, and from all actives to earth.	
8	Re-check the test instrument to see that it is still working properly.	
9	Double-check all conductors using a phase pencil or voltage stick.	
10	Disconnect all terminals and remove the cables from the motor.	
11	Insulate all disconnected terminals with tape and leave them in a safe and tidy condition.	
12	Remove the motor from its mounting.	
13	Advise the supervisor that the work is completed.	

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Review Questions 1-11	Version 4 2021

Isolation of Supplies

1. What are the three steps which must be taken to isolate a portable appliance that is connected to the supply via a plug and socket outlet?

2. What are the five steps which must be taken to isolate an electrical device that is permanently connected to fixed wiring?

3. What action should be taken if conductors are to be left disconnected while the associated machine is being worked on?

4. What type of electrical switching device is often ON in the UP position?

5. Write a valid isolation procedure for disconnecting a 5 kW, 415-volt three-phase SCI motor in a typical small factory installation. Make valid assumptions for any detail required.

ANSWERS PAGE 215

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Summary 2-1	Version 4.1 2021

2.1 - Sources of Electromotive Force

Electricity

1. Electricity is a force that is used to produce many different and often complex effects. One well known natural form of electricity is lightning. Electricity built up in clouds suddenly flows to earth. In doing so it produces large amounts of:

    a. Light - It is readily visible
    b. Heat - It can burn an object
    c. Sound - It can be heard over long distances
    d. Force - It can split and damage large trees

2. Unlike lightning, most of the electricity used in industry cannot be seen, but in most cases, it can be felt, or its effects can be seen or felt.

3. Because electricity above a certain value can be felt but not seen, electrical apparatus and installations must be treated with extreme caution. Electricity can, and often does, kill if it is not handled with care.

Methods of Producing Electricity

Thermocouple

4. If the junction of two different metals is heated, electricity is produced. The voltage depends on the types of metal and the temperature of the junction.

Magnetic/Mechanical

5. If a conductor is moved through a magnetic field a voltage is produced. This is the principle on which electric generators operate. The voltage depends on the strength of the magnetic field and the speed at which the conductor passes through it.

Friction

6. When two materials are rubbed together static electricity is produced. Lightning is a form of static electricity.

Chemical

7. If two dissimilar metals are placed in a suitable conducting liquid (an electrolyte) a voltage is produced. The voltage produced depends on the type of metal and type of conducting liquid

Light

8. When light falls on certain materials a small voltage is produced. Solar cells are used to power space satellites and as a source of electricity in remote areas.

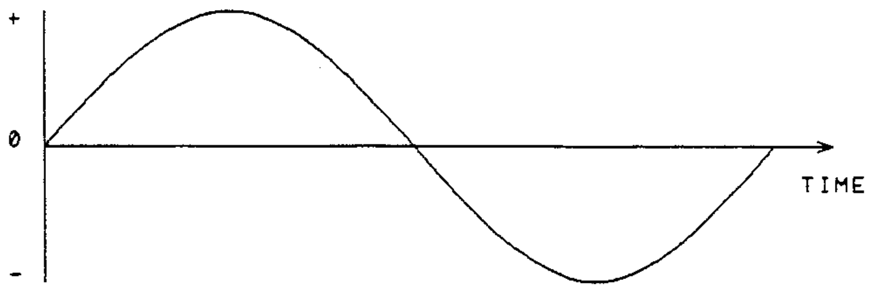
Pressure (Piezo Electric)

9. A voltage is produced when pressure is put on or taken off certain substances such as crystals or quartz. The voltage produced depends on the type of crystal and the amount of pressure.

Types of Supply

Alternating Current (A.C.)

10. This is obtained from an alternator (A.C. generator). The voltage is constantly changing in magnitude and polarity. The electrical supply provided by the network operator is alternating current.

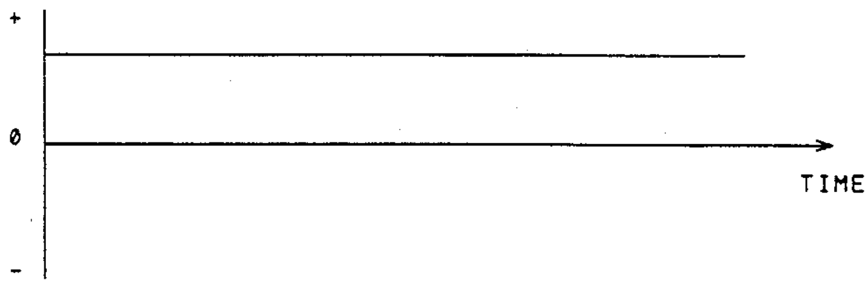


Alternating Curren

Direct Current (D.C.)

11. A D.C. supply is one in which the polarity of the supply remains constant. There are two general categories of D.C. – steady D.C. and pulsating D.C.

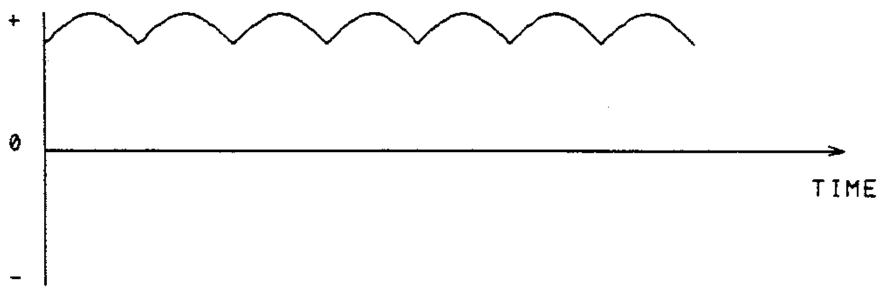
    a. Steady D.C. is obtained from devices such as batteries, cells, thermocouples and solar cells.



Direct Current

Drawings © North Metropolitan TAFE

b. Pulsating D.C. is obtained from a D.C. generator.



Pulsating Direct Current
Drawing © North Metropolitan TAFE

12. For practical purposes, the supply from a battery and that from a D.C. generator are both known as 'D.C.'.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-1	Version 4 2021

Sources of EMF

1. Describe six different methods of producing electricity. Use diagrams where necessary. State how the voltage can be increased in each case.

2. State four common effects of electric current flow.

3. Explain what is meant by the terms ‘direct current’ and ‘alternating current’. Use diagrams for your explanation.

4. What conditions are necessary for ‘galvanic corrosion’ to occur?

ANSWERS PAGE 216

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Summary 2-2	Version 4.1 2021

2.2 - Ohm's Law

1. In any direct current electrical circuit, there is a specific relationship between the voltage, the resistance and the current flow. This relationship is often expressed as 'Ohm's Law' which states that:

   "The current flowing in a d.c. the circuit or any part of a circuit is directly proportional to the applied voltage and inversely proportional to the resistance of a circuit."

2. This means that if the voltage across a particular component is increased the current flow will increase (a DIRECTLY proportional relationship), and if the resistance of the circuit is decreased the current flow will increase (an INVERSELY proportional relationship).

3. Ohm's Law can be expressed as a mathematical relationship or equation:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} \qquad \text{or} \qquad I = \frac{E}{R}$$

4. Since voltage can be expressed as an electromotive force, E (the CAUSE of the current flow), or as a potential difference (the EFFECT of the current flow), the mathematical equation for Ohm's Law can also be written as:

$$\text{Current} = \frac{\text{Potential Difference}}{\text{Resistance}} \qquad \text{or} \qquad I = \frac{V}{R}$$

5. The equation for Ohm's Law can be transposed to find any value if the other two are known, so the three ways in which Ohm's Law can be expressed are:

(Current)	(Voltage)	(Resistance)
$I = \frac{V}{R}$	$V = I \times R$	$R = \frac{V}{I}$

Example

6. Find the current flowing in the circuit in which a voltage of 24 volts d.c. is connected to a resistance of 8 ohms.

Steps for Solution

7.

a. Read the question carefully and make sure you know what value is to be found.

b. Draw a circuit diagram and insert the known values in BASIC units (e.g. amps, not milliamps if applicable).

c. Select the correct equation for the problem. $I = \dfrac{V}{R}$

d. Substitute the known values in the equation (in BASIC units). $I = \dfrac{24}{8}$

e. Solve the problem using arithmetic $I = 3$

1. Express the answer in convenient units (using Multiples or sub-multiples where required). $I = 3\ A$
=====

8. All Ohm's Law problems can be solved in the above sequence, but in circuits involving more than one component, care must be taken to use correct values in each calculation. It is often useful to add the calculated values to the diagram as they are determined.

Examples for Practice

a. How much current would flow in a circuit in which a 6-ohm resistor was connected to a 24 volt supply?

b. If 24 amps flowed in a circuit when a potential difference of 12 volts was applied to it, what would be the resistance of the circuit?

c. What voltage would have to be applied to a 100-ohm resistor to cause a current of 0.25 amps to flow through it?

d. The potential difference across a 3 kilohm resistor is 9 volts. How much current would be flowing in the circuit?

e. A particular resistor allows 2 milliamps to flow when the potential difference across it is 40 volts. What is the resistance of the resistor?

f. What value of voltage would be required to allow a current of 50 microamps to flow through a resistance of 1 megohm?

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-2	Version 4 2021

Ohm's Law

1. What are the three BASIC parts of an electrical circuit?
2. A practical electrical circuit consists of three BASIC components and two additional ones. What are the two additional components?
3. How much current would flow in a circuit in which a 3-ohm resistor was connected to a 24 volt supply?
4. If 6 amps flowed in a circuit when a potential difference of 12 volts was applied to it, what would be the resistance of the circuit?
5. What voltage would have to be applied to a 10-ohm resistor to cause a current of 5 amps to flow through it?
6. The potential difference across a 2 kilohm resistor is 20 volts. How much current would be flowing in the circuit?
7. A particular resistor allows 2 milliamps to flow when the potential difference across it is 40 volts. What is the resistance of the resistor?
8. What value of voltage would be required to allow a current of 20 microamps to flow through a resistance of 1 megohm?

<u>ANSWERS PAGE 217</u>

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 2	2-3	2021

2.3 - DC Series Circuits

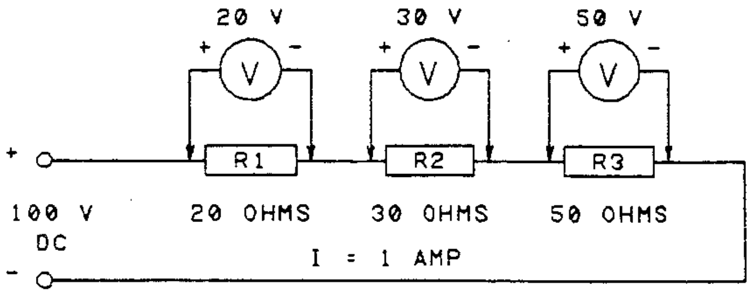
1. When resistors or other electrical components are connected ‘end-to-end they are said to be connected in SERIES. There is only ONE current path in a series circuit. Connecting resistors in series increase the total resistance of the circuit and decrease the current drawn by the circuit (if the voltage remains constant). The total resistance must be greater than the resistance of any single resistor in the series circuit. In a series circuit, the total resistance is the sum of the individual resistors.

   Total Resistance (R_T) = R1 + R2 + R3 +…

2. Total resistance is also called ‘equivalent resistance (Re or Req)’ because it is the resistance of a single resistor that could replace the entire composite circuit.

3. When an electromotive force (E) is applied to a bank of resistors in series the total current in the circuit can be found by finding the total (or equivalent) resistance, then using Ohm’s Law (I=E/R).

4. Consider a series circuit consisting of two or more resistors having different resistances. Although the total current must be the same in all parts of a series circuit, the voltage required to cause that particular value of current to flow through each resistor would be different. If each current is known and the resistance is known the voltage required for EACH resistor can be found by applying Ohm’s Law (V=I.R) to each resistor. The voltage which would be measured across each resistor is often described as the EFFECT of the flow of current in the circuit and is called ’potential difference (V)’. Applying V=I.R to the circuit above, with a current of 1 amp, the potential differences across the resistors would be 20, 30 and 50 volts respectively.



Drawing © North Metropolitan TAFE

5. The potential difference is also commonly known as ’volt drop’, ‘voltage drop’, or ‘fall in voltage’.

6. In any circuit consisting of series resistors, the potential difference across each resistor is proportional to the resistance of the resistor (because V=I.R), and the sum of the individual potential differences must be equal to the voltage applied to the circuit. The potential difference across any individual resistor in a series circuit cannot be equal to or greater than the electromotive force applied to the circuit. ALL IDENTICAL resistors in a series circuit must have the same potential difference across them.

Calculations

7. A circuit consists of three resistors connected in series to a 200 volt supply; their resistances are 20, 30 and 50 ohms respectively. Find the total resistance, total circuit current and potential difference across each resistor. Note: ALWAYS draw the circuit first. If there is more than one component of the same type, use subscripts to indicate which value is being considered in the equation.

Solutions

Resistance

$R_T = R1 + R2 + R3$

$= 20 + 30 + 50$

Total Resistance = 100 ohms

Line Current

$I = {}^{E}/_{R_T} = {}^{200}/_{100} = 2$ amps

Voltages (Potential Difference)

$V_{R1} = I.R_1$
$= 2 \times 20$
$= 40$ volts

$V_{R2} = I.R_2$
$= 2 \times 30$
$= 60$ volts

$V_{R3} = I.R_3$
$= 2 \times 50$
$= 100$ volts

8. The results of the calculation above show that the potential difference is directly proportional to the resistance (V=I.R) – the highest voltage appears across the highest resistance and vice versa.

Power Calculations

9. Having calculated the current and voltages in the circuit the power being dissipated by each part of the circuit can be calculated by applying any one of the three power equations.

$P = V \times I$ $\qquad$ $P = I^2 \times R$ $\qquad$ $P = V^2/R$

10. The total power in a circuit is the sum of the individual powers dissipated by each of the components.

Exercises

Note: You should always draw a diagram for calculation exercises.

1. Calculate the total resistance of four resistors in series if their resistances are 5, 10, 15 and 20 ohms respectively.

2. The resistance of the three resistors in a series circuit is in the ratio of 1:3:4 respectively. If the line voltage to the circuit was 80 volts, what is the potential difference across each resistor?

3. The resistance of the three resistors in a series circuit is 10 ohms, 20 ohms and 50 ohms respectively. How much current would flow in the circuit if the applied voltage was 240 volts?

4. The resistance of the three resistors in a series circuit is 10 ohms, 20 ohms and 30 ohms respectively. If the voltage drop across the 10-ohm resistor was 20 volts, what would be the total voltage applied to the circuit?

5. A switch is connected so that it can turn a 120-ohm load on and off. The voltage applied to the circuit is 240 volts. What voltage would be measured across the SWITCH when it is in the OFF position?

Typical Answers to Exercises

1. 50 Ω
2. 10:30:40
3. 3 amps
4. 120 volts
5. 240 volts

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-3	Version 4 2021

DC Series Circuits

Note: Draw a neat circuit diagram for all calculation questions.

1. What simple test can often be used to determine whether resistors are connected in series or parallel?

2. Calculate the total resistance of four resistors in series if their resistances are 10, 20, 30 and 40 ohms respectively.

3. A circuit consists of a 6 ohm, 4 ohms, and 10-ohm resistor connected in series. If all resistors in the series circuit are to be removed and replaced with a single resistor having the same resistance, what is the resistance of the single resistor?

4. What general statement can be made about the current in each component in a series circuit?

5. What general statement can be made about the sum of the voltages (potential differences) across each component?

6. Is it possible for the voltage across any one of the resistors in a series bank to exceed the line voltage?

7. What general statement can be made about the total resistance in a series circuit in relation to the resistance of any single resistor in the circuit?

8. The resistances of three resistors in a series circuit are in the ratio of 1:2:3 respectively. If the potential difference across the first resistor was 10 volts, what is the total voltage applied to the circuit?

9. The resistance of the three resistors in a series circuit is 20 ohms, 30 ohms and 50 ohms respectively. If a current of 2 amps is flowing in the 20-ohm resistor, what is the power being dissipated by the entire circuit?

10. What are two other common terms which are used to describe the ‘potential difference’ across resistors in a series circuit?

11. The resistance of the three resistors in a series circuit is 2 ohms, 4 ohms and 6 ohms respectively. How much current would flow in the circuit if the applied voltage was 24 volts?

12. The resistance of the three resistors in a series circuit are 2 ohms, 4 ohms and 6 ohms respectively, and the applied voltage is 24 volts. What is the volt drop across each resistor in the circuit?

13. Three resistors are connected in series to a 10 volt supply. What voltage would be measured across one of the resistors if it became an open circuit during the operation?

14. Two incandescent lamps are connected in a series to a 240 volt supply. A fault develops which results in one lamp being on and the other being off. What is the most likely fault?

15. Two series resistors are connected to a 24 volt supply via a single-pole switch. What voltage would be measured across the SWITCH if the lamps were on?

16. How many current paths are there in a series circuit?

17. What effect would it have on the current flow through a series circuit if the applied voltage was halved?

18. What is the equivalent resistance of a circuit consisting of 5 identical 10-ohm resistors in series if one of the resistors is open-circuited?

19. Two incandescent lamps are connected in series to a 240 volt supply. A fault develops which results in both lamps being OFF, but the voltage across one of the lamps is 240 volts, and the voltage across the other is 0 volts. What is the most likely fault?

ANSWERS PAGE 218

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Summary 2-4	Version 4.1 2021

2.4 - DC Parallel Circuits

1. When two or more components are effectively connected to the same two points as shown in the diagram below they are said to be connected in parallel. A simple test to determine whether or not the components are in parallel is to isolate the supply and disconnect one component; if it is a parallel circuit the other components in the circuit will not be affected.

2. Connecting the resistors in parallel decreases the total resistance of the circuit and increases the current drawn by the circuit (if the voltage remains constant). The total resistance must always be less than the resistance of any single resistor in the parallel circuit.

3. The voltage must be the same across all resistors connected in parallel. The current through each resistor is inversely proportional to the resistance – the higher the resistance the lower the current (I = V/R).

4. The formula for calculating the equivalent resistance of a bank of parallel resistors is as follows:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

So the total of a parallel bank of three resistors of 4 ohms, 6 ohms and 12 ohms can be calculated as:

$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12}$$

$$R_T = \frac{1}{0.25 + 0.166 + 0.083}$$

$$R_T = \frac{1}{0.4999} \quad \underline{\text{Invert}} \quad = \frac{2}{1}$$

<u>Invert Fraction</u>: - This gives a total of <u>2 ohms</u>. The total resistance in a parallel circuit is always less than the smallest resistor in the circuit.

5. The method can be used to find the total circuit resistance for any number of resistors in parallel. It is not necessary to know the line voltage to use this method.

6. If several resistors in the parallel bank have the same resistance, the total resistance may be found by dividing the resistance of one resistor by the number of resistors in parallel.

Power Calculations

7. The three power calculations are the same as those used in the series circuits

$P = V \times I$ $P = I^2 \times R$ $P = V^2/R$

Fault Finding

8. In practical circuits, components are often connected in parallel. For fault finding purposes it is necessary to be able to predict the behaviour of a circuit under fault conditions. If one branch circuit in a parallel bank becomes OPEN circuited, the result is:

- The total circuit resistance increases.
- The total circuit current decreases.
- The voltage across the remaining branches remains the same.
- The voltage drop across the open circuit is equal to the applied voltage.
- The voltage across the open-circuited component falls to zero.

9. If one branch circuit in a parallel bank is SHORT circuited, the result is:

- The total circuit resistance decreases to zero.
- The total circuit current increases to a value limited only by the current available from the power supply. (The circuit protection device should operate).
- The voltage across the remaining branches falls to zero.
- The voltage across the short-circuited component falls to zero.

Exercises

Note: Always draw a diagram with any calculation.

a. Find the total resistance of two resistors connected in parallel if their values are 1 ohm and 1 megohm respectively.

b. Find the total resistance of two resistors connected in parallel if their values are 36.25 ohms and 79.68 ohms respectively.

c. Find the total resistance of three resistors connected in parallel if their values are 0.25 ohms, 1.6 ohms and 0.01 ohms respectively.

d. Find the total resistance of ten identical resistors connected in parallel if the resistance of each is 500 ohms.

e. Three resistors are connected in parallel to a 240 volt supply; the line current is 4 amps. If one of the resistors was safely disconnected, would the line current increase or decrease?

f. Three resistors are connected in parallel. One resistor is dissipating 48 watts, another has a resistance of 2 ohms, and the third has a current of 2 amps flowing through it and the voltage across it is 24 volts. What is the total resistance of the circuit? What is the total power dissipated by the entire circuit?

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-4	Version 4 2021

DC Parallel Circuits

1. Calculate the total resistance of four resistors in parallel if their resistances are 4, 8, 12 and 24 ohms respectively.

2. What simple test can often be used to determine whether resistors are connected in series or parallel?

3. A circuit consists of a 6 ohm, 3 ohms and 2-ohm resistor connected in parallel. If all of the resistors in the parallel circuit are to be removed and replaced with a single resistor having the same resistance, what is the resistance of the single resistor?

4. What general statement can be made about the voltage across each component in a parallel circuit?

5. What general statement can be made about the sum of the individual currents in the components in a parallel resistor circuit?

6. Is it possible for the current through any one of the resistors in a parallel resistance bank to exceed the line current?

7. What general statement can be made about the total resistance in a parallel circuit in relation to the resistance of any single resistor in the circuit?

8. The resistance of the three resistors in a parallel circuit is in the ratio of 1:2:3 respectively. If the total current through the first resistor was 12 amps, what is the total current flowing in the circuit?

9. The resistance of the three resistors in a parallel circuit is 20 ohms, 30 ohms and 60 ohms respectively. If a current of 10 amps is flowing in the 20-ohm resistor, what is the power being dissipated by the entire circuit?

10. The resistance of the three resistors in a parallel circuit is 3 ohms, 6 ohms and 12 ohms respectively. How much current would flow in the circuit if the applied voltage was 24 volts?

<u>ANSWERS PAGE 219</u>

a)

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Summary 2-5	Version 4.1 2021

2.5 - DC Series/Parallel Circuits

1. A series-parallel circuit is a circuit in which some components are connected in a series and some are connected in parallel. The principles used to determine the values in series and parallel resistive circuits apply in the same way to relevant parts of a series/parallel resistive circuit, but care must be taken to use the appropriate values for each calculation.

2. Ohm's Law can be applied to an entire D.C. circuit or any part of the circuit. If an entire circuit is being considered the TOTAL values of current, voltage and resistance must be used. If part of a circuit is being considered, only values of current, voltage and resistance for THAT PART must be used.

3. A typical sequence for resolving series/parallel circuits which involve a single voltage source is:

   - Draw a circuit diagram and indicate the given values. Sections of the circuit should be identified with letters or numbers as required.
   - Calculate the equivalent resistance of the parallel resistors.
   - Find the total resistance of the circuit by adding the equivalent resistance of the parallel banks to the series resistors.
   - Calculate the total circuit current using Ohm's Law (I=E/R).
   - Calculate the potential difference (or volt drop) across each resistor using Ohm's Law (V=I.R). Note that the potential difference across resistors in parallel is common to all resistors in the parallel bank.
   - Add the potential differences together; the result should be the voltage applied to the circuit.
   - Calculate the current through each resistor in the parallel banks using Ohm's Law (I=V/R). The voltage value to use must be the value calculated in step e. – it is not the line voltage unless the resistors are connected directly across the supply.
   - Calculate the power dissipated by applying any one of the three power equations to each component or group of components.

DC Series/Parallel Circuits

Note: Draw a neat circuit diagram for all calculation questions

1. A 12-ohm resistor is connected in parallel with a 6-ohm resistor and the pair are connected in series with another resistor of 20 ohms. What is the equivalent resistance of the entire circuit?

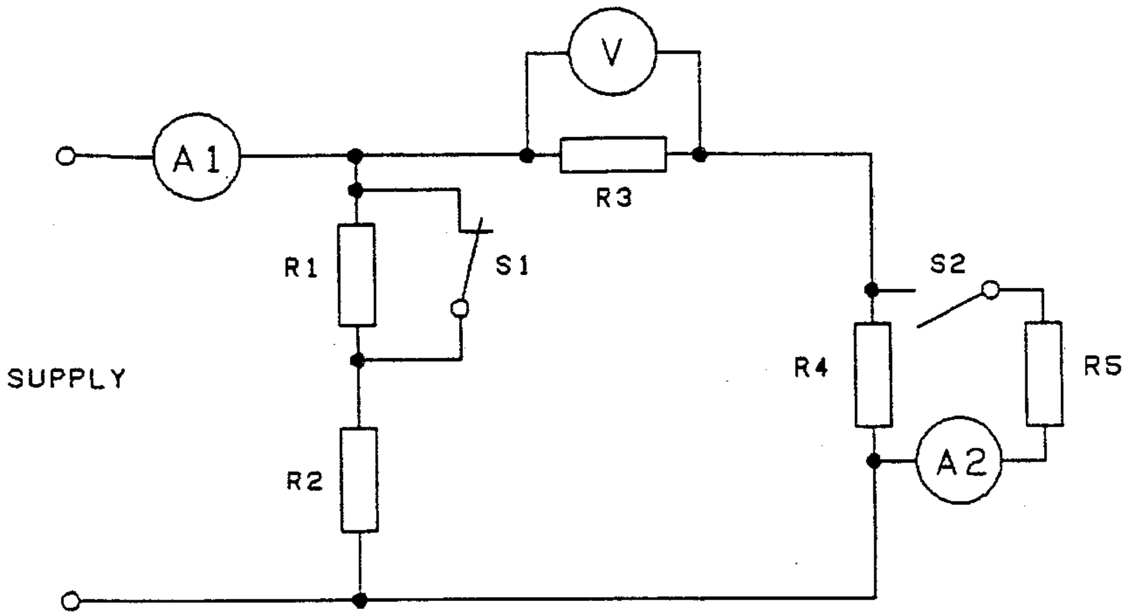
2. One of the resistors in a particular series-parallel circuit becomes short-circuited. Does the total resistance of the circuit increase or decrease?

3. Refer to Circuit 1.
Complete the table of values for the circuit for the following operating conditions:
The line voltage is 240 volts
R_2 is dissipating 480 watts
The voltmeter V is indicating 80 volts
R_4 has a resistance of 160 ohms
S1 is closed and S2 is open
R_1 and R_5 each have a resistance of 100 ohms

	R	**I**	**V**	**P**
R_1				
R_2				
R_3				
R_4				
R_5				

Line				

Circuit 1



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<u>ANSWERS PAGE 220</u>

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Summary 2-6	Version 4.1 2021

2.6 - The A.C. Waveform and Phasors

Advantages of A.C.

1. Alternating current is used for supply authority distribution systems because it has several advantages over a direct current distribution system. The main advantages include:

    - The voltage can be increased or decreased more easily and economically using transformers.
    - A.C. motors are often simpler, more reliable and require less maintenance than D.C. motors.
    - A three-phase A.C. supply system provides two voltage levels comparatively simply.
    - A.C. can be transmitted over long distances at high voltages with minimum losses.
    - Large A.C. generators (alternators) are generally easier to build and maintain than D.C. generators.

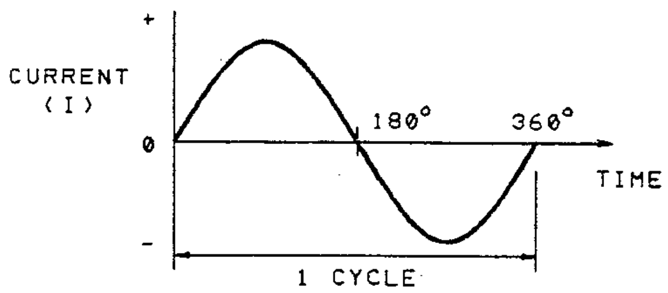
2. Although A.C. is generally more economical to produce and distribute than D.C. the behaviour of A.C. is much more complex than D.C. because the effects of inductance and capacitance are of major significance and because of the characteristics of the sine wave (or sine curve).

Waveforms

3. It is frequently necessary to describe a voltage or current by graphing its value over a given period of time.

4. An alternating current waveform is a graph of the magnitude and polarity of the current for one complete cycle - a cycle is the time taken for the process to begin repeating itself. The number of cycles that occur in a given period is called the frequency and is usually expressed in cycles per second. The unit 'cycles per second' is given a special name Hertz (Hz).

5. The frequency of the 240/415 volt a.c. the supply system is 50 Hz (50 cycles per second). The time taken to complete one cycle of a continuous waveform is known as the period (p), so the period for a 50 Hz waveform is 0.02 seconds. These relationships for a single-phase a.c.. sine wave is shown graphically in the figure below.



Period = $^1/f$ (seconds)

Frequency = $^1/p$ (Hz)

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Values of A.C.

7. The mathematical properties of an a.c. sine wave is such that there are several values associated with it; these are:

a.	The instantaneous value.	E_P. sin ø		
b.	The peak value.	E_P		
c.	The average value	0.637 E_P		
d.	The root means square value (RMS).	0.707 E_P		
e.	The peak to peak value.	$2E_P$		

Note: V can replace E

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-6	Version 4 2021

The A.C. Waveform and Phasors

1. What condition is necessary for a voltage to be induced in a conductor by a magnetic field?
2. How much voltage is induced in a conductor when it is moved parallel to the flux in a magnetic field?
3. What is the most common name for the rotating electrical device used to produce an alternating current?
4. What effect does it have on the frequency of the output from an alternator if the number of magnetic poles is increased?
5. In what units is frequency usually expressed?
6. What is the meaning of the term Hertz when it is applied to the specification of frequency?
7. A conductor is moving uniformly within a two-pole magnetic field system. At what point(s) is the induced voltage maximum?
8. What is the frequency of the A.C. distribution system in Perth?
9. What is the QUANTITY symbol -for frequency?
10. What is the customary UNIT symbol for expressing the frequency of an A.C. distribution system?
11. What are the four 'values' of alternating current?
12. What peak value of A.C. voltage would be required to produce the same heating effect as 100 volts DC?
13. What value of DC voltage would be required to produce the same heating effect as 100 volts peak A.C.?
14. What is the RMS value of an A.C. sine curve?
15. What is the AVERAGE value of an A.C. sine curve over half of one cycle?
16. Calculate the peak-to-peak value of a sinusoidal wave which has an RMS value of 240 volts.
17. What is the peak value of the single-phase A.C. supply voltage in the Perth metropolitan area?
18. What value of A.C. are most standard measuring instruments designed to indicate?
19. What is the AVERAGE value of a sine wave between 0 and 360 degrees?

ANSWERS PAGE 221

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Summary 2-7	Version 4.1 2021

2.7 - Power Factor

A.C. Power

1. There are various types of power in an A.C. circuit – TRUE power (P), measured in watts (W), APPARENT power (S), measured in volt-amps (VA), and REACTIVE power (Q), measured in volt-amps reactive (Var). Power factor is the ratio between true power and apparent power in any circuit. (It is also the cosine of the angle the current leads or lags the applied voltage: a leading power factor when a circuit is more capacitive or a lagging power factor when the circuit is more inductive - ie motors.)

2. True power (P) is the power that is doing useful work in a circuit – usually converting electrical energy into heat energy, as in a heating element, or converting electrical energy into mechanical energy as in an electric motor. True power is the power measured on a wattmeter.

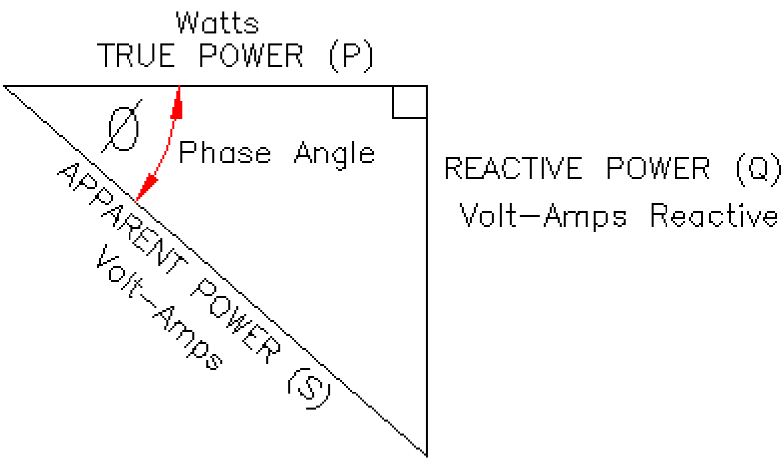
3. Apparent power (S) is the product of the line voltage and the line current (V times I) on A.C. Apparent power cannot be measured directly it can only be calculated from other circuit measurements. In inductive and capacitive circuits (reactive circuits) the current is out of phase with the applied voltage so power is not the direct product of voltage and current. The angle of lead or lag has to be taken into account.

4. Reactive power (Q) is the power stored in an A.C. reactive component (as a magnetic field in an inductor or as an electrostatic field in a capacitor) and returned to the mains during part of each half-cycle. Reactive power is not usually measured directly but it can be calculated from other circuit measurements. Reactive power is sometimes referred to as 'wattless' power and the related current is called 'wattless' current.

Power Triangle

5. The relationship between the various types of power can be shown on a special phasor diagram known as a 'power triangle', in which the true power is shown as a horizontal phasor pointing from left to right. A power triangle (see Figure 1) is similar in shape to an impedance triangle.

True Power = Energy Used
Apparent Power = Energy Supplied
Reactive Power = Energy Wasted



Drawing © North Metropolitan TAFE

Figure 1 – A power triangle

From trigonometry Cos. ϕ = Adjacent / Hypotenuse

= True power/Apparent power

= POWER FACTOR

True power = Apparent Power x Cos. ϕ

= Applied Voltage x Line current x Cos. Φ

= V_Z x I_Z x Cos. ϕ

6. The instruments necessary to measure the required values to construct a power triangle are shown in Figure 2.

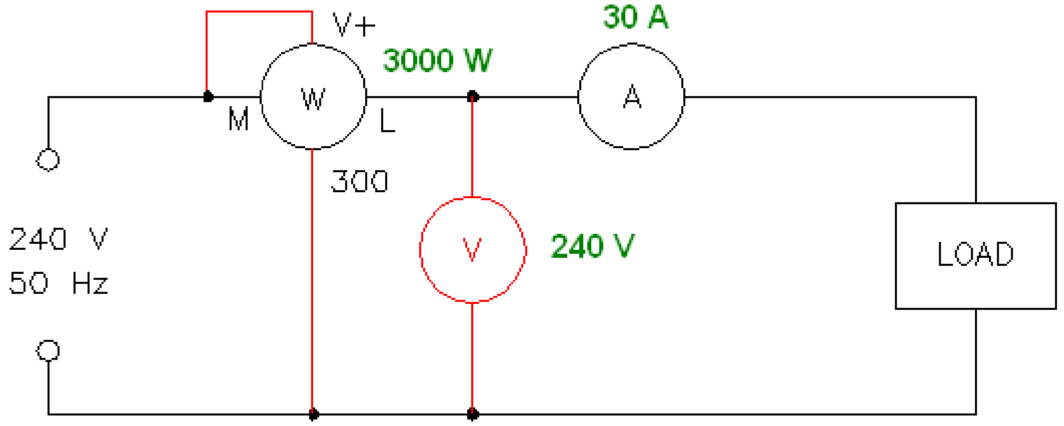


Figure 2 *Drawing © North Metropolitan TAFE*

7. The most important aspect to maintaining a power factor as close to 1 as possible is reduced line current. A power Factor of 1 gives a ϕ angle of 0 degrees (see cos 0 degrees) and means that there is no reactive power and apparent power is equal to true power. If line current is kept lower we do not have to increase the current ratings of all the components in the distribution and supply system that would be the case of an uncorrected circuit.

Fully loaded transformers and motors run closer to unity than do unloaded motors and transformers.

In the electrical Industry, the most common method to correct single-phase devices power factor is by putting a capacitor in parallel with inductive loads.

A resistive circuit has a power factor of 1 as there are no reactive components.

According to the Western Australian Distribution Connections Manual (produced by Western Power), a power factor range for loads of less than 1 MVA connected to the distribution system is prescribed to be 0.8 lagging to 0.8 leading.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Questions 2-7	Version 4 2021

A.C. Power

1. An a.c. the circuit has a line current of 10 amps, a line voltage of 240 volts and a wattmeter reading of 1000 watts. What is the value of APPARENT POWER in the circuit?

2. An a.c. the circuit has a line current of 20 amps, a line voltage of 240 volts and a wattmeter reading of 2000 watts. What is the value of TRUE POWER in the circuit?

3. An a.c. the circuit has a line current of 30 amps, a line voltage of 240 volts and a wattmeter reading of 3000 watts. What is the value of REACTIVE POWER in the circuit?

4. Draw a typical POWER triangle for a series or parallel RLC A.C. circuit?

5. How is the 'POWER FACTOR' of an A.C. circuit usually defined?

6. What is the maximum possible value of the power factor in a sinusoidal A.C. circuit?

7. What three common measuring instruments are required to determine the power factor of an a.c. circuit (not including a power factor meter)?

8. An inductive a.c. the circuit has a line current of 20 amps, a line voltage of 240 volts and a wattmeter reading of 4000 watts. What is the power factor of the circuit?

9. What is the 'MAIN' undesirable effect of operating a circuit at a low power factor?

10. What is the most common method of improving the power factor of an inductive A.C. circuit?

11. What safety precaution should be taken before working on a large power factor correction capacitor that has just been disconnected from the mains?

12. What is the capacity of the largest capacity power factor correction capacitor that may be installed without a discharge path according to AS/NZS3000:2007? State the Clause number.

13. What effect does it have on the power factor of a three-phase circuit if several three-phase induction motors are operated with light loads?

14. What is the lowest permissible power factor in a.c? circuits in Western Australia?

ANSWERS PAGE 222

2.

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 2	2-8	2021

2.8 - Electrical Reticulation

Reticulation

1. The various stages in transmission and distribution of electricity in Western Australia are shown in Figure 1. The system consists of:

   a. Step-up transformers at the generating stations (330 kV, 132 kV).

   b. Primary distribution to terminals and sub-stations.

   c. Sub-distribution to transformers (66 kV, 33 kV, 22 kV).

   d. Secondary distribution H.T. (High Tension) via high voltage radial feeders to other reduction transformers. Metropolitan areas: 1l kV; Rural areas 19. l kV, 12.7 kV.

   e. L.T. (Low Tension) distribution transformers, normally pole mounted. Most new suburbs are now using underground reticulation with 240 volts single phase. Rural areas: 480/240 volts single phase.

Three-phase Supply

2. Substations in the city and suburbs are fed at 66 kV from Cannington and other switchyards. Distribution in the Perth city area is at 11 kV by underground cables, while in the suburban areas feeders from substations are either 22 kV or 6.6 kV to pole-mounted transformers near the locality requiring power. In-country towns, the feed to pole-mounted distribution transformers is at 22 kV, three-phase. For normal power distribution in cities and suburbs and country towns, a three-phase, four-wire street mains network is adopted, giving the consumer a 415 volt, three-phase, or 240 volts single-phase 50 Hz supply, as required. This is obtained from the low tension side of the three-phase pole-mounted transformers.

Rural, Single-phase Supply 'Single Wire Earth Return' or SWER System

3. Farms and small country industries not in towns are supplied at 12.7 kV by single-phase spur lines from 22 kV, three-phase, overhead, feeder lines used for rural distribution. Light galvanised steel wire is used for these single-phase spur lines and only the 'active', or 'live' conductor is insulated from earth. The return, or 'neutral', the conductor is earthed every 600 metres and at every transformer. Pole mounted transformers at each consumer point, reduce the single-phase 12.7 kV spur line voltage to 240 volts for lighting and power up to 1.5 kW motors. Where larger motors are required, the 12.7 kV is transformed to 480 volts, and single-phase motors up to 7.5 kW may be operated at this voltage. Motors larger than 7.5 kW can normally only be connected to a three-phase system.

```
                            +=============+
                            |  Generating |
                            |   Station   |
                            +==-=======-==+
                               |       |
                             330 kV  123 kV  (Primary Distribution)
                               |       |
                          +-------------------+
                          | Terminal or Zone |
                          |    Sub-Station   |
                          +-------------------+
                               |   |   |  Sub-Distribution
          +---------------------+   |   +----------------------+
          |                         |                          |
         33 kV                     66 kV                      22 kV
   +-------------+          +-------------+          +--------------+
+--|             |          |             |          |              |--+
|  +-------------+          +-------------+          +--------------+  |
|         |                         |   Secondary Distribution|        |
|         |                         |                         |        |
|         |                         |                         |        |
|         |                         |                         |        |
|         |                         |                         |        |
|        11 kV                     11 kV                     11 kV     |
|  +-------------+          +-------------+          +--------------+  |
|  |             |          |             |          |              |  |
|  +-------------+          +-------------+          +--------------+  |
|                                   |  Low Tension Distribution        |
|                                   |                                  |
|                                   |                                  |
|                          400/230 V  50 Hz                            |
|                          415/240 V  50 Hz                            |
|                       Single and Three-phase                        |
|                           +-------------+                            |
|                           |  Consumer  |                             |
|                           +-------------+                            |
|                                                                      |
|                                                                      |
|                                                                      |
|                                                                      |
|                          Rural Distribution                          |
|                                                                      |
+---------+ 19.1 kV                                 12.7 kV +----------+
   +------------+                                    +------------+
   |Transformer|                                     |Transformer|
   +------------+                                    +------------+

                              480/240 V
                             Single-phase
                            +-------------+
                            |   Rural    |
                            |  Consumer  |
                            +-------------+
```

Figure 1 - Main power distribution system in W.A.

Multiple Earthed Neutral (MEN) System

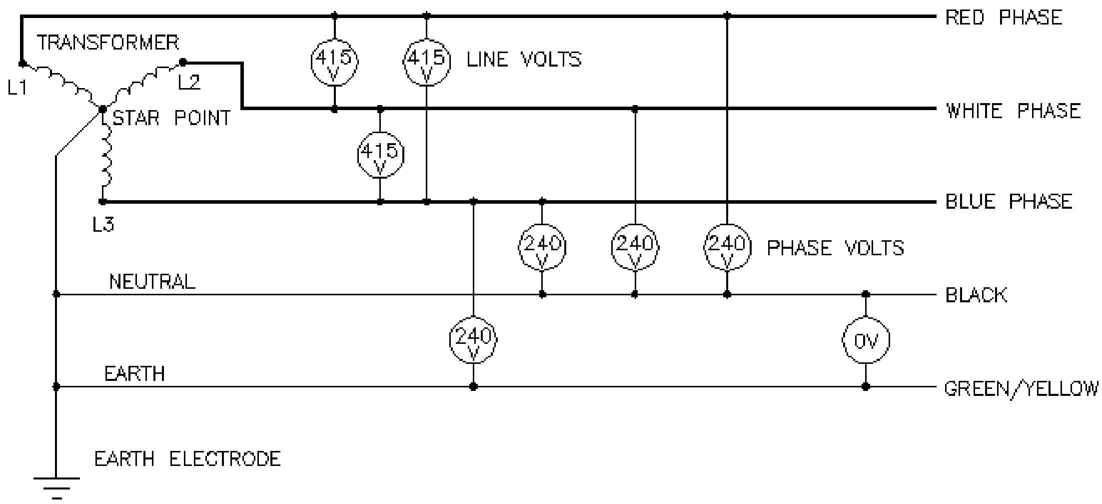
4. The Multiple Earthed Neutral (MEN) System is a system of earthing in which the parts of an installation required to be earthed are connected to the general mass of earth and in addition, are connected within the installation to the neutral conductor of the supply system.

5. The MEN system of earthing is widely used in W.A. for domestic, industrial and commercial installations. All parts of the installation required to be earthed are connected to a main earthing conductor which is connected to a buried or driven earth electrode located near the switchboard; the main earthing conductor is then connected to the neutral link, either directly, or via an earth bar or link.

6. It is customary to connect the main earthing conductor to a terminal at one extremity of the neutral bar or link, with the main neutral connected to the adjacent terminal.

7. The three-phase four-wire system used to supply individual consumers in W.A. is shown in Figure 2. All voltages are given as RMS values.

8. Most domestic installations are supplied with a single-phase (240 volts, 50 Hz); a three-phase supply is only provided where a specific need exists.



Drawing © North Metropolitan TAFE

Note: The voltages specified in AS/NZS 3000 Wiring Rules are based on a **400/230**-volt three-phase distribution system.

Figure 2 - Three-phase four-wire distribution system

High Voltage Supplies

9. High voltage supplies are any electrical supply systems intended to operate at voltages above 1000 volts rims a.c. High voltage supplies are potentially hazardous because it is not essential to touch a live part to receive an electric shock. Air can normally be regarded as an insulator at voltages below about 1000 volts, but at higher voltages, it can become a temporary conductor.

10. The minimum permissible working distance from exposed live parts under normal working conditions are:

    above 650 volts to:
    22 000 volts (Nominal) 700 mm
    33 000 volts (Nominal) 700 mm
    66 000 volts (Nominal) 1000 mm
    132 000 volts (Nominal) 1200 mm
    220 000 volts (Nominal) 1800 mm
    330 000 volts (Nominal) 2800 mm

11. These shall be the distances beyond the reach of any part of the body or any conducting body or unapproved object touching any part of the body.

12. Work on or close to high voltage installations must only be carried out by persons who have had appropriate training, and who have an appropriate safe working permit. An A-Grade electrical worker's licence alone is not sufficient to qualify an electrical worker to work on high voltage installations.

13. Persons who intend to or are required to work on high voltage equipment after switching, isolation and earthing must be appropriately instructed and provided with a safe work permit by an authorised person (HV switching operator). These are specialised safety requirements. Refer to Energy Safety for further information if required.

14. Specific high voltage training courses are conducted by Energy Safety from time to time – usually at their Jandakot training facility.

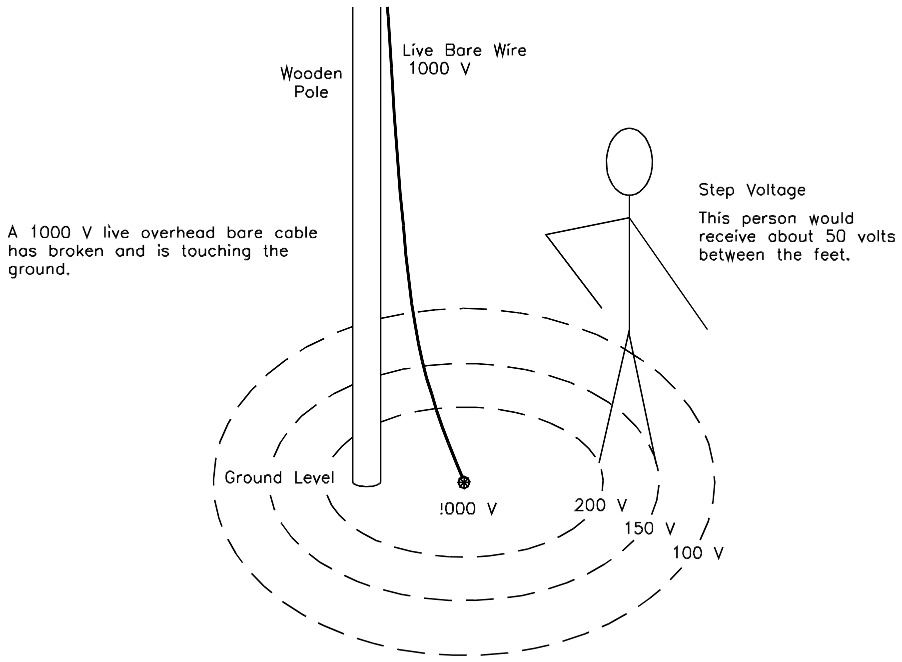
15. The object of the requirements is to provide an environment that allows safe operation of the high voltage electrical equipment and in which protection for both authorized personnel and the public is afforded.

16. Common terms associated with supply system voltages are:

    a. **Touch current** Electric current which passes through a human body or an animal body when that body touches one or more accessible parts of electrical equipment or an electrical installation, under normal conditions or fault conditions. (see AS/NZS 3000 Clause 1.4.94)

    b. **Touch voltage** Touch voltage is an r.m.s voltage that may appear, under earth-fault conditions, between an object touched by hand and the ground beneath the feet. (see AS 2067 Clause 3.9.6 and AS/ZS 3000 Clause 1.4.95).

    c. **Step Voltage** – an r.m.s voltage that may appear, under earth fault conditions, between the points of contact of each foot with the ground, the feet being spaced about 900 mm apart (see AS 2067 Clause 3.9.7).



Drawing © North Metropolitan TAFE

e. **Creepage distance** is the shortest path between two conductive parts, or between a conductive part and the bonding surface of the equipment, measured along the surface of the insulating material (see AS/NZS 3100 Clause 2.1.17).

f. **Induced voltage –** A voltage that occurs in a conductive component as a result of the effects of adjacent invisible magnetic fields without a specific electrical connection to any live part.

17. The specific control measures for dealing with high voltage installations include:

a. Switching/Isolation procedures
b. Earthing of equipment during maintenance
c. Erection of barriers
d. Restricting access to hazardous areas
e. Placement of safety signs and labels
f. Suitability of associated equipment
g. Control and indicate equipment
h. Circuit protection devices
I. Busbar and switching arrangements
j. Emergency exit facilities
k. Fire protection arrangements
l. Separation of HV and LV systems
m. Size and resistance of earthing conductors
n. Ratings and installation of HV cables
o. HV testing to ensure the suitability of equipment
p. Use of on-site safety observers

18. Specific requirements for high voltage installations are contained in AS/NZS 3000 Clause 7.6 - High Voltage Electrical Installations.

19. Section 7 of the W.A. Electrical Requirements contains local requirements for consumers high voltage installations in the range of 1 kV to 33 kV. The principles are contained in Clause 7.1 as reproduced below:

> ‘Consumers High Voltage installations must be designed by persons with engineering competence and an understanding of the effects of voltages exceeding 1 kV and associated high load and fault currents. The High Voltage installation must be designed, constructed, maintained and operated to ensure the safety of personnel. To achieve this, systems for access, egress, movement of people vehicles and machinery, earthing and signage must be implemented.’

20. Inquiries relating to high voltage supply and installations should be directed to the Network Operator's offices. For supply at voltages greater than 33 kV inquiries should be directed to the Transmission System Operator.

21. The W.A. Electrical Requirements is available free of charge on the Internet at the address www.energy.wa.gov.au.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-8	Version 4 2021

Electrical Reticulation

1. What are the nominal voltages available in the three-phase supply to domestic installations in WA?

2. What is the frequency of the three-phase supply to domestic installations in WA?

3. What is the major factor which results in high voltage installations being a potentially higher risk than lower lethal voltages such as 415/240 (400/230) volts?

4. Is a current A Grade Electrical Worker’s Licence sufficient qualification to allow the holder to perform electrical work on high voltage supplies?

5. How is ‘high voltage’ defined according to AS/NZS 3000 Wiring Rules?

6. Which W.A. government authority can be consulted for advice on safety aspects of working on or around high voltage installations?

7. Explain in your own words what is meant by the term ‘Touch Current’. State the AS/NZS 3000 Clause number (if applicable).

8. Explain in your own words what is meant by the term ‘Touch Voltage’. State the AS/NZS 3000 Clause number (if applicable).

9. Explain in your own words what is meant by the term ‘Creepage Distance’.

10. Explain in your own words what is meant by the term ‘Step Voltage’ when applied to fault conditions in a high voltage distribution system?

11. How can high voltage parts be identified in a typical electrical installation?

12. Name and describe six control measures that can be taken to reduce the risks associated with working on or around HV installations.

13. Which clause in AS/NZS 3000:2000 describes requirements for high voltage installations?

14. Which clause in the W.A. Electrical Requirements describes requirements for high voltage installations?

<u>ANSWERS PAGE 223</u>

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 2	2-9	2021

2.9 - Regulatory Requirements

Technical Standards

1. The electricity supplied to domestic and industrial installations is potentially hazardous in that a person (or animal) coming in contact with a live part could result in death or injury, or it could cause direct or indirect damage to property. To minimise the risks associated with the use of electricity, various types of legislation have been enacted and technical standards have been developed.

2. Technical standards are documents that specify the minimum requirements for safety and proper operation of equipment and they are usually supported by relevant legislation to give them the force of law. Technical standards are prepared by relevant experts in the field and are frequently updated by committees established for the purpose. They are arranged by technical topics - such as Electrical Installations, Hazardous Areas, Interior Lighting, Emergency Evacuation Lighting, Telecommunications Cabling Installations, Electrical Drawing Symbols and so on. There are thousands of such standards, covering virtually every conceivable technical topic. Appendix A of the Wiring Rules lists the documents referred to in the Wiring Rules.

3. The electrical technical standards in use in Australia have been developed (usually by Standards Australia) with due regard for international practice as published by other organisations such as Standards New Zealand, the International Organisation for Standardisation (ISO), the International Electrotechnical Commission (IEC) and British Standards (BS). Reference to such organisations is frequently found on electrical equipment and in technical publications.

Main Publications

4. The main publications which set out requirements and procedures relating to electrical work in W.A. are current editions of:

a. Electricity (Licensing) Regulations 1991

b. The Wiring Rules (Australian/NZ Standard AS/NZS 3000).

c. WA Electrical Requirements.

d. AS/NZS 3008.1.- Electrical installations - Selection of cables. Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian conditions.

e. AS/NZS 3012 Electrical Installations - Construction and demolition sites

f. AS/NZS 3017 Electrical installations - Testing guidelines.

g AS/NZS 3018 Electrical Installations - Domestic Installations

h. WA Health (Public Buildings) Regulations.

i. The W.A. Mines Safety and Inspection Regulations.

j. AS/NZS 3760 In-service safety inspection and testing of equipment.

k. AS/NZS 4836 Safe working on low voltage electrical installations

l. AS 2430.3.1 Classification of hazardous areas. Examples of area classifications - General.

m. AS 2381.1 Electrical equipment for explosive atmospheres - Selection, installation and maintenance. Part 1 - General requirements

Electricity (Licensing) Regulations 1991

5. The Electricity (Licensing) Regulations 1991 are regulations made under the authority of the WA Electricity Act. The Regulations form the legislative framework for such matters as the establishment of the WA Electrical Licensing Board, licensing of electrical workers and electrical contractors, regulation of electrical work, supervision of electrical apprentices, and the reporting of electrical accidents. It is the responsibility of each electrical work to be familiar with the requirements of these regulations.

6. The Electricity (Licensing) Regulations 1991 provide for penalties to be imposed for non-compliance with the requirements in WA, including fines and suspension or cancellation of electrical worker's licences.

7. The Electricity (Licensing) Regulations 1991 require electrical workers to carry out work in accordance with the Wiring Rules, the WA Electrical Requirements and various other relevant Australian Standards (See Regulation 49).

8. The Regulations require persons who perform electrical work to be licensed. For the Regulations, 'electrical work' is defined on Page 2 as:

> '... work on electrical machines or instruments, on an electrical installation or on electrical appliances or equipment to which electricity is supplied or intended to be supplied at a nominal pressure exceeding 50 volts alternating current or 115 volts direct current whether or not the thing on which the work is performed is part of, or is connected to or to be connected to, any distribution works or private generating plant and, where work is performed on any appliance, whether or not electricity is supplied thereto through an electrical plug socket or socket outlet'

9. The Regulations define 'electrical installation work' as:

> '... the work of assembling and fixing in place, altering or adding to any electrical installation or maintaining, enhancing repairing, removing, or, connecting to fixed wiring, any electrical equipment.'

The Wiring Rules (AS/NZS 3000 Current Edition including Amendments)

10. The Wiring Rules is a technical standard that set out the minimum requirements for the design, construction and testing of electrical installations, including the selection and installation of electrical equipment forming part of such electrical installations (See AS/NZS 3000: Clause 1.1).
11. The requirements are intended to protect persons, livestock and property from electric shock, fire and physical injury hazards that may arise from an electrical installation that is used with reasonable care and with due regard to the intended purpose of the electrical installation.

12. Although you need to memorise several important requirements in the publications listed above, it is usually only necessary to be able to find a particular requirement quickly, particularly in the Wiring Rules. The general structure of the Wiring Rules is:

13. Amendments are issued from time to time. You must insert these amendments in the book as soon as they are issued. Record the insertion of amendments inside the front cover of the book. The Wiring Rules is usually re-printed, with amendments, at about five-year intervals. When a re-print is issued the previous edition must be discarded. The current edition (AS/NZS 3000:2000) is significantly different from the previous edition (AS 3000:1991), as outlined in the Preface on page 2.

14. **Clause Numbering** Clauses are numbered according to a type of decimal system, for example, Clause 5.5.1.2 (a)(i). Clauses are sometimes referred to as 'rules' or 'paragraphs'.

15. **Contents** The Contents is located at the front of the book. It is usually used to locate sections in the book which relate to specific broad topics. It is also used to locate the page number for Appendices, Tables and Figures. The Contents does not list the topics in alphabetical order so it is not easy to locate detailed requirements.

16. **Index** You should use the INDEX to find a particular requirement. The Contents is not usually suitable for this purpose. The sub-parts of each title in the Index are listed in alphabetical order. For example, see:

    Earthing

      Conductor

        Installation

17. There are four different types of print used in the Wiring Rules. Each type has a specific purpose, as explained in the Foreword:

Bold print:	**Statements of principle**.
Normal print:	The mandatory requirements of the Clause.
Italic print:	*Exceptions to mandatory requirements.*
Reduced print:	Explanatory notes.

18. The electrical terms used in the Wiring Rules often have precise meanings that can be found by referring to Section 1 (Scope and Fundamental Safety Principles) Clause 1.4. Definitions

19. The Wiring Rules is not a textbook - it does not contain information relating to the principle of operation of electrical devices. The reader is expected to be familiar with the terms used, except for those specifically defined in Section 1. The same general principle applies to all technical standards.

Procedure

20. The procedure which you should use to find the answer to a given question is:

a. Read the question carefully.

b. Select a KEYWORD (it may not be written as part of the question).

c. Look up that keyword and find the relevant Clause (paragraph) or Table number from the Index.

d. Look up that Clause or Table (Note that the index does not give page numbers).

e. Ask yourself "does that Clause answer the question?".

If YES - go to step f. below.
If NO - go back to paragraph b. above.

f. Read the Clauses before and after the one selected, and be sure to look up any other rules referred to in that Clause.

g. Write down the answer in your own words.

h. Quote the Clause or Table number as part of your answer.

Example

21. What is the minimum permissible size of the main copper earthing conductor in a domestic installation with 10 square mm mains? The keyword sequence is:

Earthing
Conductor
Main
Size 5.3.3.2

Answer: 4 square mm cable. Clause 5.3.3.2 and Table 5.1

22. For assessment purposes, answers to questions relating to the specific requirements of the Wiring Rules must include the relevant Clause or Table number.

23. The purposes of this module are Section is to gain an understanding of the AS/NZS 3000

24. Clause 1.5 outlines the fundamental principles that all electrical installations must maintain
a. 1.5.1 Protection against dangers and damage
b 1.5.2 Control and Isolation
c. 1.5.3 Protection against electric shock
d. 1.5.4 Basic protection (protection against direct contact)
e. 1.5.5 Fault protection (protection against indirect contact)
f. 1.5.6 Addition protection by the use of RCD’s
g 1.5.7 Basic and fault protection by the use of extra-low voltage
h. 1.5.8 Protection against thermal effects in normal use
i. 1.5.9 Protection against overcurrent
j. 1.5.10 protection against earth fault currents
k. 1.5.11 protect against abnormal voltages
l. 1.5.12 Protection against the spread of fire
m. 1.5.13 Protection against injury from mechanical movement
n .1.5.13 Protection against external influences

Exercise

25. The following exercise indicates the type of information that can be found in the Wiring Rules.

a. What are the permissible colours of the following electrical cables used in fixed wiring?

Active: ____________________
Neutral: ____________________
Switchwire: ____________________
Earth: ____________________
Clause No:______________

b. Is it permissible to use the cable colour yellow for cables in fixed wiring?

Answer: _________________________________ Clause No:______________

c. What are the usual colours of the cable cores in internationally colour coded THREE core flexible cords?

Answer: _________________________________ Clause No:______________

d. What is the maximum permissible resistance of a main earthing conductor?

Answer: _________________________________ Clause No:______________

e. What are the four methods of protecting DIRECT contact with live electrical parts?

Answer: _________________________________ Clause No:______________

f. What are the maximum and minimum operating temperatures for PVC insulated (V75) cables according to the Wiring Rules?

Answer: _________________________________ Clause No:______________

g. What are the three methods of protecting INDIRECT contact with live electrical parts?

Answer: _________________________________ Clause No:______________

h. Every motor shall be provided with a switching device capable of performing three functions. Identify the three functions.

Answer: _________________________________ Clause No:______________

i. Which Section in the Wiring Rules provides information relating to the visual inspection and testing of electrical installation?

Answer: ________________________________ Clause No:______________

26. More detailed requirements relating to electrical cables and their applications are covered later in this module.

WA Electrical Requirements

27. The WA Electrical Requirements is a publication issued by the WA supply authority. It contains service rules, mandatory requirements, and guidelines and information relating to electrical installations in WA.

28. Section 12 of the publication WA Electrical Requirements provides additional information relating to special requirements for consumers mains and residual current devices (RCDs) in installations in WA. Section 10 of WAER provides information relating to supply to construction sites, including temporary supplies.

AS/NZS 3008.1.1 Electrical installations - Selection of cables

29. AS/NZS 3008.1.1 is the technical standard that specifies the requirements for the selection of cables for a particular purpose. Previous editions of the Wiring Rules contained limited information relating to cable selection, but this is no longer the case in AS/NZS 3000 It is now essential to refer to AS 3008 for cable selection.

30. AS/NZS 3008.1.1 provides for cable selection based on:

   a. Current-carrying capacity.
   b. Voltage drop.
   c. Short circuit temperature rise.

31. Cable selection based on AS/NZS 3008.1.1 usually requires reference to one or more tables of information, and the tables often make use of diagrams to illustrate different installation conditions. One of the keys to using AS/NZS 3008.1.1 is to know what tables are provided and when to use them. It is also essential to read the footnotes to tables whenever they are used.

AS/NZS 3012 Electrical installations - Construction and demolition sites

32. AS/NZS 3012 is the technical standard that specifies the requirements for electrical installations which supply electricity to appliances and equipment on construction and demotion sites, and for the in-service testing of portable, transportable and fixed electrical equipment used on construction and demolition sites.

AS/NZS 3760 In-service safety inspection and testing of electrical equipment

33. AS/NZS 3760:2003 is a technical standard that specifies procedures for the in-service safety inspection and testing of equipment, other than fixed equipment, which is designed for connection by a flexible power supply cord and plug, to a low voltage supply. It also applies to cord extension sets, electrical portable outlet devices, cord connected portable residual current devices and portable isolation transformers.

WA Health (Public Buildings) Regulations 1992

34. The WA Health (Public Buildings) Regulations sets out regulations relating to several physical aspects of the construction of public buildings such as seating arrangements, exit doors, evacuation plans, artificial lighting, emergency lighting, switchboards, generating equipment and maintenance.

W.A. Mines Safety and Inspection Regulations 1995

35. The Mines Safety and Inspection Regulations 1995 sets out regulations governing safety and inspection aspects of mining operations. Section 5 contains specific requirements relating to Electricity in mines including licensing of electrical workers, electrical supervisors, high voltage installations, electrical cables, earthing systems, earth leakage protection and labelling of equipment.

36. Paragraphs 5.19 to 5.21 and 5.31 detail specific requirements regarding the types of cables that are required to be used in mines, the type of protection that must be provided for the cables, and general requirements regarding their installation.

General

37. A common aspect of the terminology used in Australian technical standards is the use of the terms 'shall' and 'should'. 'Shall' indicates that a statement is mandatory, and 'should' indicates a recommendation.

38. The publications outlined above, and others, will be the subject of more detailed consideration in other modules. It is the responsibility of the licensed electrical worker to be aware that there are regulations and technical standards applying to the work they are performing in any given situation and to comply with them where applicable.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-9	Version 4 2021

Regulatory Requirements

1. Which Section in the Wiring Rules contains information relating to the SCOPE of the Wiring Rules, and fundamental safety principles?

2. Does the Wiring Rules usually provide information relating to the principle of operation of electrical devices?

3. Which Section in the Wiring Rules contains the main requirements relating to EARTHING arrangements?

4. Which Section in the Wiring Rules contains the main requirements relating to the TESTING of installations?

5. What is the AS/NZS number of the standard which must be used in conjunction with the Wiring Rules to determine the current carrying capacity of cables?

6. What is the name of the supply authority publication which contains information relating to the local requirements for RCDs for residential electrical installations in WA?

7. What is the name of the publication which contains information relating to specific requirements for the installation of cables in mines in W.A.?

8. What is the highest voltage a person may work on without being in possession of a current Electrical Worker's License in WA?

9. What aspect of electrical work is covered by AS/NZS 3760?

10. What aspect of electrical work is covered by AS/NZS 3012?

11. Which publication relates to the licensing of electrical workers and supervision of electrical work in WA?

12. What is the distinction between the use of the words 'shall' and 'should' in Australian technical standards?

13. Does the electricity regulatory authority in W.A. have the authority to take formal legal action against people who breach the requirements of the Wiring Rules or the WA Electrical Requirements?

14. Which Section of the WA Electrical Requirements provides information relating to the provision of temporary power supplies on construction sites?

ANSWERS PAGE 224

2.10 - Protection Principles and Earthing

Principles of Protection

1. The Wiring Rules (Clause 1.5) provide **fundamental principles** for the protection against the physiological effects of current flow. Protection can be achieved by preventing a current from passing through the body of any person or limiting the current that can pass through a body to a value lower than the shock current.

2. Protection against direct contact with live parts can include:

   a. The insulation of live parts.

   b. The use of barriers or enclosures.

   c. The use of obstacles.

   d. The placing of live parts out of reach.

3. Methods of protecting indirect contact with exposed conductive parts that can become live under fault conditions can include (see AS/NZS 3000 Clause 1.5.4):

   a. preventing a fault current from passing through the body.

   b. Limiting the fault current that can pass through the body to a lower value than the shock current.

   c. Automatic disconnection of the supply on the occurrence of a designed fault current.

4. Protection against the dangers that may arise from contact with exposed conductive parts may be provided by means including the following:

   a. The automatic disconnection of the supply.

   b. The use of double insulation.

   c. The suitable location of exposed conductive parts.

   d. The use of equipotential bonding.

   e. The electrical separation of exposed conductive parts.

5. The purpose of an earthing system is to automatically disconnect the supply if a live conductor comes in direct contact with the exposed metal frame of an electrical appliance or device. The supply is automatically disconnected when sufficient current flows in the circuit to operate the circuit protection device such as a fuse or circuit breaker, thus protecting against electric shock in case of a fault. The only permissible colour for an insulated earthing conductor is green/yellow.

6 The condition in which the resistance between any part of the circuit and the exposed metal frame of an appliance (i.e. the insulation resistance) is below specified limits is known as an 'earth fault' or low insulation resistance to earth.

7. The earthing system in use for the distribution system in W.A. is the multiple earthed neutral (MEN) system. In this system the parts of the installation which are required to be earthed are connected to the general mass of earth within the installation, and, in addition, are connected within the installation to the neutral conductor of the supply system (at one point - the neutral link). See AS/NZS 3000:2000 (Wiring Rules) Clause 1-4-62 and 5.3. Two other systems of earthing are the Direct Earthing System and the voltage-operated Earth Leakage Circuit Breaker system.

Appliance Insulation Classifications

8. Electrical appliances are manufactured to one of three insulation specifications, namely:

a. **Single Insulated** In a single insulated appliance there is one layer of insulation between the internal live components and the outer metal enclosure. See Clause 1.4.27 - Class I equipment.

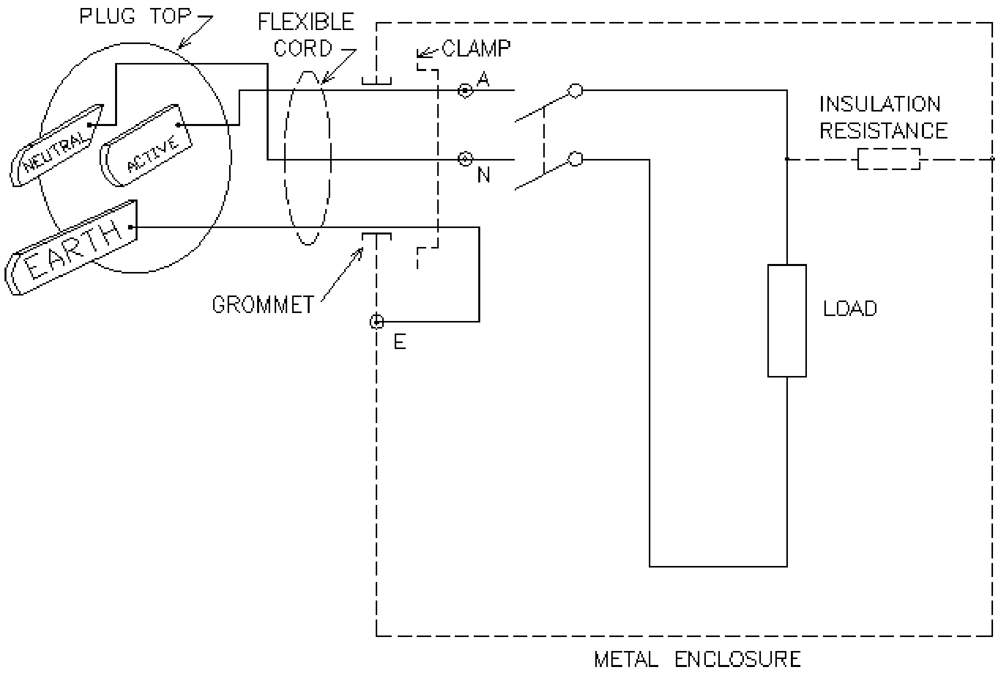
b. **Double Insulated** In a double-insulated appliance there are two layers of insulation between the internal live components and the outer metal enclosure; the layers of insulation are called the functional layer and the protective layer. The international symbol to indicate double insulation is one square inside another. Double insulated appliances must NOT have exposed metal connected to the earth, and they have a warning label such as 'DO NOT EARTH - DOUBLE INSULATED'. See Clause 1.4.28 Class II equipment and 1.4.60.

c. **All Insulated** All insulated appliances have no exposed metal parts so they do not have an earth.

9. Many electrical appliances which operate at voltages exceeding 32 volts a.c. are of the single insulated type. Single insulated devices must never be connected to the supply unless the exposed metal is connected to the general mass of earth via the earthing conductor in the flexible cord and the earthed pin in the socket outlet. Live terminals or parts must not be accessible to users of electrical equipment.

Effects of Earthing

10. Figure 1. Shows an outline circuit of a typical single insulated appliance.



Drawing © North Metropolitan TAFE

Figure 1. - Outline circuit of a single insulated appliance

11. If the component labelled 'insulation resistance' in Figure 1 had a resistance approaching zero ohms (i.e. it was a short circuit), and the operating switch was turned on, the active from the three-pin plug top would be connected directly to the outer metal casing so the full supply voltage would be present between the outer casing and earth. If the earthing conductor was correctly connected a high current would flow from the outer casing to earth via the earth in the socket outlet and the circuit protection device (fuse or circuit breaker) protecting the circuit would operate and automatically isolate the circuit from the supply.

12. If the earthing conductor was not connected, or if it was not able to carry the current required to operate the circuit protection device, the outer metal casing would remain alive; any person touching the frame while in contact with any earth would suffer an electric shock.

13. Earthing an appliance does not provide protection against electric shock if a person touches the active and neutral or active and earth simultaneously. Earthing an appliance does not prevent faults from occurring, nor does it correct any faults; it only removes the supply from the fault section of the circuit. For an earth fault to cause the fuse or circuit breaker to interrupt the circuit, sufficient fault current must flow in the earthing conductor to be able to operate the protective device. If there was too much resistance in the earthing circuit the protective device may not operate because of the resulting comparatively low current. Therefore the AS/NZS 3000 (Wiring Rules) specifies that the resistance of protective earthing conductors shall be low enough to permit the passage of current necessary to operate the protective device. The requirements for fault-loop impedance are contained in Appendix B of AS/NZS 3000.

Isolating Transformers

14. In some situations it is considered necessary to isolate the neutral from the earth to reduce the possibility of electric shock if a person accidentally touches a live wire while, for example, standing on a concrete floor. Isolation can be achieved by using an isolating transformer. An isolation transformer is an a.c. the device in which 240 volts is applied to the input and 240 volts is taken from the output. The construction of a double wound transformer is such that there is no electrical connection between the input winding and the output winding, so there will no longer be a voltage between active and earth. An isolation transformer must not be used to supply more than one unearthed appliance. If two unearthed single insulated appliances were connected to a single isolating transformer at the same time, and an earth fault developed in both appliances, it would be possible for a dangerous voltage to exist between the metal casings of the appliances.

Wiring Rules Requirements

15. The requirements for earthing are contained in Section 5 of the Wiring Rules; samples of the requirements are given below.

16. Where a portable single insulated appliance is supplied by a flexible cord and is connected to the supply via a plug and socket-outlet, provision must be made for the earthing pin to automatically make contact first and break contact last, (see Clause 5.5.4.4). This is achieved by making the earth pin in the plug-top longer than the other pins.

17. It is not permissible to connect an earthing conductor to an appliance using a screw or bolt which is used to secure a terminal box cover or fix the equipment in position if removal of the screw would reduce the effectiveness of the earthing connection (see Clause 5.5.6.2).

18. An 'earthed situation' is a situation wherein there is a reasonable chance of a person touching the exposed metal of an appliance and, at the same time, coming in contact with the earth (see Clause 1.4.44).

Equipotential Bonding

19. Equipotential bonding is the process of connecting metallic water piping, waste pipes and other extraneous metal in contact with the ground and access to personal contact, with the earthing system of the building. Equipotential bonding conductors are treated in the same way as earthing conductors. See Clause 1.4.52 - Equipotential bonding.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-10	Version 4 2021

Protection Principles and Earthing

1. What is the main reason why single insulated 240-volt equipment must be earthed?

2. An EARTHED SITUATION is where there is a reasonable chance of a person touching .....?..... and at the same time coming in contact with the earth. (Give the Wiring Rules Clause or Table Number)

3. Any situation within .....?..... metres of a concrete floor or metal pipe is deemed to be an earthed situation. (Give the Wiring Rules Clause or Table Number)

4. Is it necessary for Earth Equipment complying with AS/NZS 3100 for double insulation? (Give the Wiring Rules Clause or Table Number)

5. What are the only permissible colours for an insulated earthing conductor? (Give the Wiring Rules Clause or Table Number)

6. Describe two of the methods of protection listed in AS/NZS 3000 for protection against direct contact with live parts.

7. Which Figure in AS/NZS 3000 shows the parts of a ‘fault loop’ in a MEN system?

8. What are the three major types of risk for which protection must be provided according to AS/NZS 3000 Fundamental Principles? Give the Clause number.

ANSWERS PAGE 226

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Review Questions	Version 4
Electrical Trades	EFRP Section 2	2-10b	2021

Earthing Requirements

1. Should 240 volt double insulated (Class II) portable appliances be earthed?

2. What is the internationally recognised symbol which means 'double insulated - Do not earth'?

3. Is it permissible to earth equipment by connect exposed metal to an earthing conductor which is being used to earth equipment supplied from another distribution board?

4. How must a hinged door of a metallic electrical cubicle be earthed?

5. The exposed metal of electrical equipment on a wheeled overhead gantry crane is required to be earthed. Can metal-to-metal contact between the wheels and the rail be regarded as an effective connection for the purposes of earthing?

6. A particular electric motor is to be fixed in position using four bolts with nuts. Is it permissible to use one of the fixing bolts as the earthing terminal?

7. What is the general meaning of the term 'equipotential bonding'?

ANSWERS PAGE 227

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Summary 2-11	Version 4.1 2021

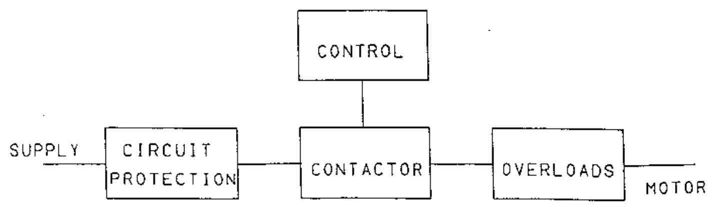
2.11 - Electrical Diagrams

1. An electrical diagram is a pictorial representation of an electrical circuit. Various types are used to convey information to the user, such as how the circuit operates, how the components are connected, or where they are located. In most cases, components are represented by symbols.

2. Electrical diagrams can be presented in numerous forms, but the three main ones used to depict control and power circuits (as distinct from architectural drawings such as floor plans and site plans) are:

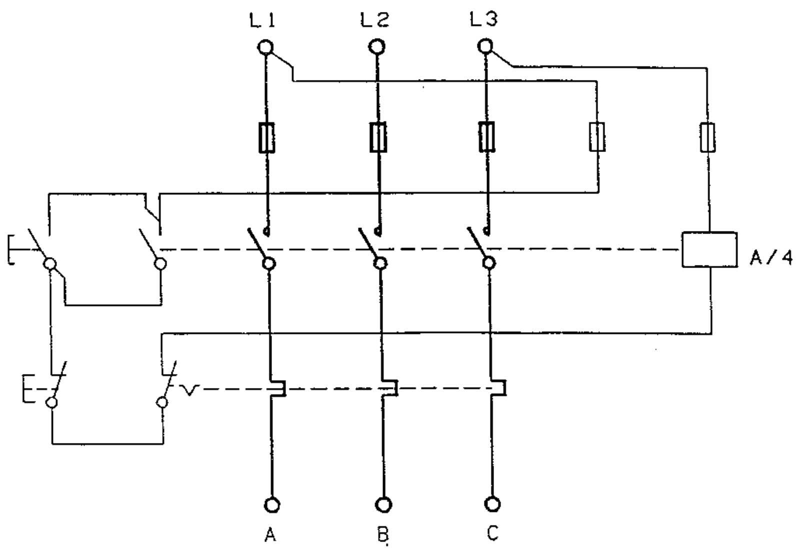
Block Diagrams

3. A block diagram shows the main sections of a circuit without showing the individual connections between components. They can provide an outline of the sequence of operation within the circuit and are read from left to right or top to bottom. A simple example of a block diagram is shown below.



Wiring Diagrams

4. A wiring diagram shows the physical relationship between the components (not necessarily to scale), and the actual location of the terminals and wiring between them. All connections are shown at the terminal at which they are made. An example of a wiring diagram is shown below.



Drawings © North Metropolitan TAFE

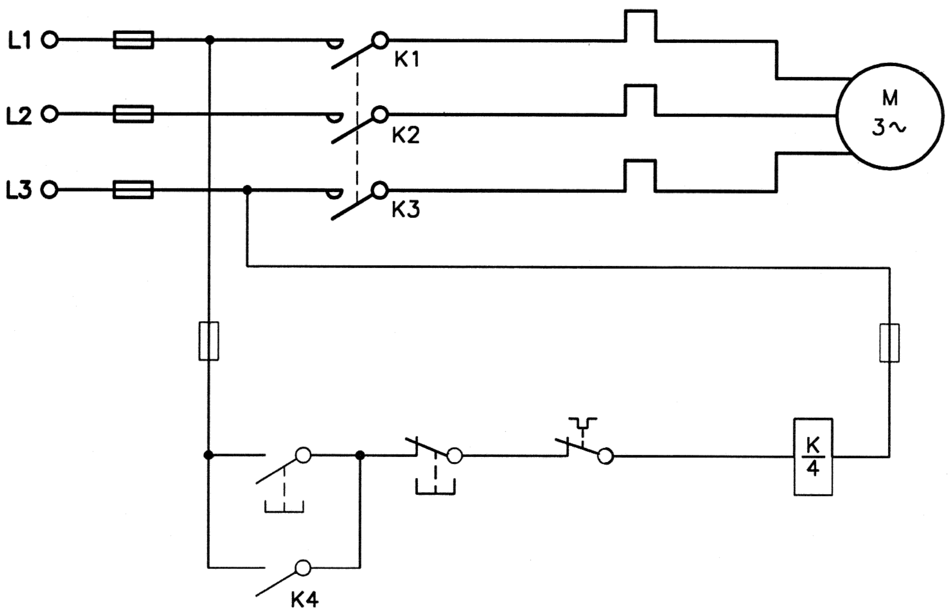
5. Typical uses for a wiring diagram include:

   a. Checking the actual wiring between components in a piece of electrical equipment.
   b. Wiring up a particular piece of equipment.
   c. Locating the individual components in a piece of equipment.

Circuit Diagrams

6. Circuit diagrams show the detailed operation of a circuit in its simplest form. They are drawn to aid the rapid understanding of how a circuit operates, but they give no indication of the physical position of the components, nor do they give any indication where the conductors terminate - all connections are shown in conductors, not at actual terminals. Circuit diagrams were previously known as 'schematic diagrams'.

7. Electrical components in circuit diagrams are represented by symbols. Australian Standard symbols are published in the AS 1102 series, but there are several different standards throughout the world and some manufacturers use their standards (or a combination of standard and non-standard symbols) so it is sometimes necessary to work out the meaning of a symbol from its position in the circuit. An example of a circuit diagram, using Australian Standard symbols, is shown below.



Drawing © North Metropolitan TAFE

8. Typical uses for a circuit diagram include:

   a. Checking the detailed operation of a circuit.
   b. Locating operational faults in a particular circuit or
   c. installation using logical reasoning

9. Most circuit diagrams use 'detached representation' to show the location of symbols. In this method, the individual parts of a multi-part component (such as a relay coil and its associated contacts) are shown in different locations on the diagram, but they are given labels to show their relationship. This method results in a considerable simplification of the drawing, but it can cause problems when identifying the various parts of a component.

10. Some drawings have a 'legend' to identify the symbols used on the drawing or to enable the reader to distinguish between symbols of the same type

Conventions

11. To be able to read a circuit diagram you need to be familiar with the common drawing symbols, and you need to know the conventions used for presenting information in electrical drawings. The most important conventions are:

    a. All equipment and components are drawn in the UNOPERATED CONDITION (i.e. when no current is flowing in the circuit). This convention is most important in circuits involving magnetic relays and contactors.

    b. Conductors are represented by STRAIGHT vertical or horizontal lines wherever possible - angled lines should only be used where it is unavoidable.

    c. All components are represented by symbols - preferably to Australian Standards.

    d. Cause and effect are from left to right or top to bottom - the electrical supply is shown on the left or at the top. If the supply is shown on the left, and the sequence of operation is from top to bottom it is called a horizontal arrangement, sometimes being referred to as a "ladder" diagram. If the supply is shown at the top, and the sequence of operation is from left to right, it is known as a vertical arrangement.

    e. Lines depicting electrical conductors can be of different thicknesses to differentiate between circuits - high current (e.g. power) circuits are often shown with thicker lines than lower current (e.g. control) circuits.

    f. Components with specific symbols (e.g. a start button) are not named on the drawing unless to distinguish them from other components of the same type on the same drawing or series of drawings. If it becomes necessary to name components it is customary to assign to them a code, then show the full name in a legend (e.g. TDRI and TDR2 for two-time delay relays).

    g. Joins between conductors are shown in conductors in circuit diagrams and at terminals in wiring diagrams.

    h. Junctions in conductors in circuit diagrams are shown with a dot (with a diameter of twice the line thickness of the conductor). Conductors which cross but are not joined are NOT shown with a loop.

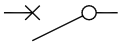
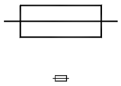
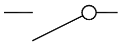
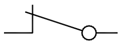
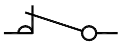
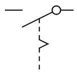
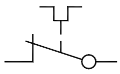
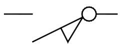
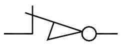
    i. Switching components are drawn in such a way that the operation of the moving portion of the switch is in a clockwise direction.

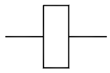
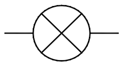
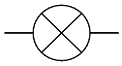
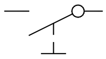
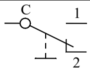
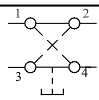
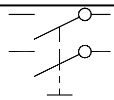
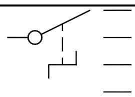
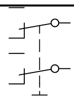
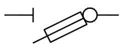
    j. The size of drawing symbols remains relatively constant even though the size of a drawing sheet may change. A symbol drawn on A4 paper does not double in size if the sheet size is increased to A3.

    k. The numbers of contacts operated by a contactor or relay are shown under the abbreviated name of the contactor or relay coil. Actual contacts are labelled with the abbreviation for the contactor or relay by which they are operated, followed by the respective number for that contact.

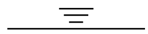
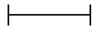
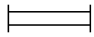
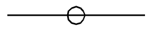
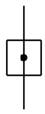
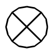
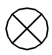
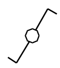
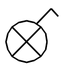
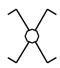
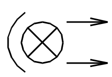
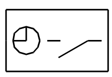
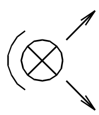
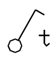
Electrical Drawing Symbols

12. The recommended drawing symbols for electrical components are contained in an Australian Standard, AS 1102. The symbols used in this module generally conform to AS 1102, but some non-standard symbols are used because you are likely to use many diagrams which were drawn before new standards were published.

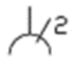
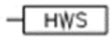
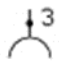
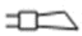
A		Circuit Breaker
B		Control Fuse
C		NO Contact Control
D		NC Contact Control
E		NO Contact Power
F		NC Contact Power
G		NO Overload Manual Reset
H		NC Overload Thermal
I		NO Limit Switch
J		NC Limit Switch

K		Relay Coil
L		Lamp Signal
M		Lamp Filament
N		Toggle Switch
O		Two Way Toggle Switch
P		Intermediate Switch
Q		Double Pole Switch
U		Rotary Switch
R		Double Pole Double Throw Switch
S		Switch Fuse Isolator

Sheet 4 — ARCHITECTURAL LOCATION SYMBOLS — To AS 1102 (1986)

	DESCRIPTION	SYMBOL		DESCRIPTION	SYMBOL
1	SWITCHBOARD (Main Switchboard)	MSB	11	EMERGENCY LIGHTING LUMINAIRE	
2	UNDERGROUND LINE		12	FLUORESCENT LAMP (single) (double)	 
3	OVERHEAD LINE		13	ONE–WAY SWITCH Single Pole Two Pole Three Pole	  
4	MAINS ENTRY BOX				
5	LUMINAIRE General symbol		14	SINGLE POLE PULL SWITCH	
6	LUMINAIRE Fixed to wall		15	DIMMER SWITCH	
7	LUMINAIRE Group of lamps eg. three 40W	 3 x 40 W	16	TWO–WAY SWITCH	
8	LUMINAIRE With built–in switch		17	INTERMEDIATE SWITCH	
9	SPOTLIGHT		18	TIME SWITCH	
10	FLOODLIGHT		19	PERIOD LIMITING SWITCH	

Sheet 5 ARCHITECTURAL LOCATION SYMBOLS

	DESCRIPTION	SYMBOL		DESCRIPTION	SYMBOL
20	GPO Single Phase		30	PUSH BUTTON SWITCH	
21	GPO - double		31	ELECTRICAL APPLIANCE General Symbol HWS - Hot Water System AC - Air Conditioner EF - Exhaust Fan	 
22	THREE PHASE SOCKET OUTLET				
23	TELEPHONE OUTLET				
24	CLOCK B Battery D Digital S Synchronous				
25	MOTOR General Symbol				
26	DC POWER SUPPLY Rectifier Unit				
27	ELECTRIC BELL				
28	ELECTRIC BUZZER				
29	HORN				

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 2	Review Questions 2-11	Version 4 2021

Electrical Diagrams

1. What is the MOST important convention which must be known when reading an electrical circuit diagram?

2. If a particular electrical circuit diagram shows some conductors as thick lines and others as thin lines, what do the THICK lines represent?

3. Which type of electrical drawing shows the actual connections between individual terminals?

4. What type of electrical drawing usually shows connections in CONDUCTORS rather than at the actual terminals of the components?

5. What type of electrical drawing is most suitable for checking the existing wiring in a circuit?

6. What type of electrical drawing is best suited to showing the DETAILED operation of the circuit?

7. Draw the correct Australian Standard Symbol for each of the following:

   a. stop button
   b. fuse
   c. relay contact - normally open
   d. relay coil
   e. thermal overload heater element

8. Draw the correct Australian Standard Architectural Symbol for each of the following :

   a. Main Switch Board
   b. flood light
   c. twin fluorescent
   d. double socket outlet (GPO)
   e. intermediate switch

ANSWERS PAGE 228

3.1 - Single-phase Transformers

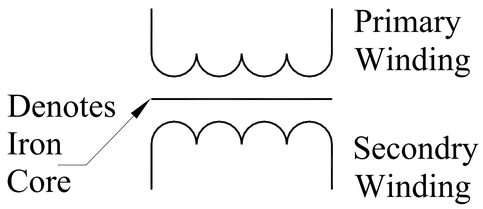
1. A transformer is a stationary device used to increase or decrease the voltage of an A.C. supply with very low losses. A transformer has at least 2 windings wound on a magnetic core. The winding connected to the input is called the PRIMARY (Pri) and the winding connected to the output is called the SECONDARY (Sec).

2. The core is usually made from a high-quality laminated stalloy or ferrite, to reduce iron losses such as eddy currents and hysteresis. Many small to medium-sized transformers use grain-oriented 'C Cores' instead of laminations. Various lamination shapes are available such as the C core and shell-type.

3. Electrical insulation in the form of an oxide, a powder, or a thin mylar film is provided between laminations. This insulation should not be damaged. Ferrite is a very good magnetic conductor but it is a very poor electrical conductor.

Double Wound Transformer

4. In this type, the primary and secondary windings are insulated electrically, but they are connected magnetically.



Drawing © North Metropolitan TAFE

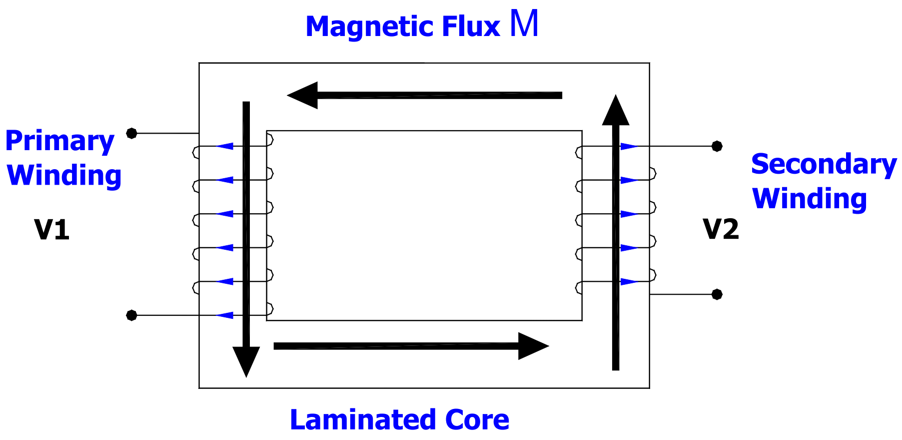
5. If the output voltage is higher than the input, it is a STEP-UP transformer. If the output voltage is lower than the input, it is known as a STEP-DOWN transformer. In a STEP-DOWN transformer, the resistance of the primary winding is usually higher than the resistance of the secondary winding and visa versa.

6. Single-phase transformer cores are available in two main shapes known as the 'core type' and the 'shell type'.

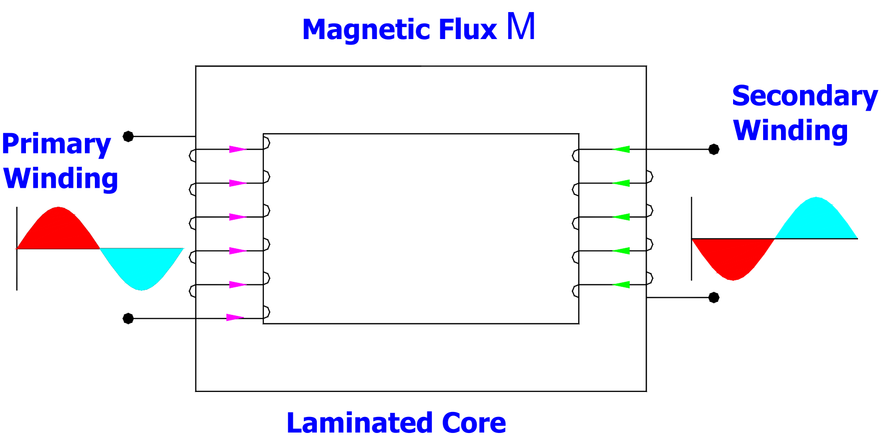
Transformer Operation

7. No-Load Condition. When a supply voltage V1 is applied to the primary winding a self-induced voltage V1’ is produced (Lenz's Law) in the primary winding and opposes the applied voltage V1.

8. On no-load, voltage V1 practically equals voltage V1' and the no-load current or excitation current is usually about 1% to 3% of the rated full load current.



9. The self-induced voltage V1' is 180 degrees out of phase with the primary voltage V1 as shown below.



Drawings © North Metropolitan TAFE

10. On no-load, the secondary voltage is also 180 degrees out of phase with the primary voltage V1 but the value of the induced voltage will be governed by the number of turns.

11. Effect on Load. When the load is switched on the secondary current produces a de-magnetising force. Consequently, the flux is reduced, thus reducing the self-induced voltage (or back EMF) in the primary. The difference between the back EMF in the primary and the supply voltage is increased and more current flows in the primary.

12. Since the primary current is proportional to the secondary current and the primary voltage is proportional to the secondary voltage:

    Primary VA = Secondary VA (neglecting losses)

13. The voltage ratio is the ratio between the primary voltage and the secondary voltage.

    Voltage Ratio = Vp:Vs

14. The turns ratio is the ratio between the primary turns and the secondary turns. The turns ratio is the same as the voltage ratio in a transformer.

    Turns Ratio = Np:Ns {N is the symbol for turns in a coil}.

15. Any variations of secondary current are accompanied by a proportional variation of the primary current.
Therefore:

$$\frac{Vs}{Vp} \quad \frac{Ns}{Np} \quad \frac{Ip}{Is}$$

Where:

Is	=	secondary current	Vp	=	primary voltage
Ip	=	primary current	Ns	=	secondary turns
Vs	=	secondary voltage	Np	=	primary turns

Transformer Ratings

16. Transformers and alternators are not rated in kilowatts (kW) because the load is drawn from a transformer may have a variable power factor, so they are rated in volt-amperes (VA) or kilo volt-amperes (kVA) which are derived from the line voltage and the line current. In all transformers, the output kVA from the secondary is equal to the input kVA less any losses in the transformer.

AS/NZS 3000: (Wiring Rules)

17. The main Wiring Rules applicable to transformers begin at Clause 4.14

Transformer Losses

18. The magnetic core of a transformer consists of many thin laminations of high-grade silicon steel (Stalloy). The power absorbed by the core of the transformer is called the 'iron loss' and is due to EDDY currents and Hysteresis. Eddy currents are reduced by using a laminated or ferrite powder iron core instead of a solid block.

19. Hysteresis losses can be reduced by using a better quality iron, which has less residual magnetism or remanence, but higher quality irons are expensive, so most manufacturers use lower quality iron and allow for losses in the design of the device.

Applications in Industry

20. Transformers are widely used in industry. Typical applications include:

- Power supplies.
- Western Power substations - high voltage for transmission.
- Arc welding machines.
- Isolating transformers - for electrical safety.
- Impedance matching - electronic circuits.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-1	Version 4 2021

Single-phase Transformers

1. Can typical single-phase transformers be used to raise or lower DC voltages?
2. What are the names given to the two windings on a basic single-phase step-down transformer?
3. Which winding on a basic single-phase step-down transformer has the lowest DC resistance?
4. What is the phase relationship between the primary and secondary voltage in a single-phase double wound transformer?
5. What name is given to a basic transformer in which the primary and secondary windings are electrically separate from each other?
6. To which winding in a single-phase double wound step-down transformer is the input voltage normally connected?
7. From which winding in a single-phase double wound step-down transformer is the output voltage normally taken?
8. What name is given to a transformer in which the secondary voltage is greater than the primary voltage?
9. From what material is the core of a power transformer normally made?
10. What are the names given to the two basic types of single-phase transformer core?
11. Laminated steel is commonly used in the construction of a power transformer. What other type of material is used for the same purpose in very small transformers?
12. What is the name given to the type of transformer secondary coil which can deliver more than one output voltage without changing the connections or voltage to the primary winding?
13. What are the two main types of losses in a power transformer?
14. What name is given to a transformer in which the input voltage is the same value as the output voltage?
15. Which winding in a single-phase step down transformer is usually wound with the smallest diameter winding wire?
16. What is the main purpose of an isolating transformer?
17. What dangerous situation can arise if the input voltage is accidentally connected to the secondary of a 240/6 volt single-phase double wound step-down transformer?
18. A particular single-phase transformer has a nominal output rating of 5 kVA at 125 volts. What is the nominal input rating (neglecting losses)?

19. A particular 240-volt single-phase step-down shell type transformer has 1200 turns on the primary and 300 turns on the secondary. What is the output voltage on no-load?

20. If a single-phase double wound step-down transformer has a voltage ratio of 6 to 1, what is the turns ratio?

21. When does a double wound transformer operate at its highest operational power factor?

22. A particular 240-volt single-phase shell type transformer has 600 turns on the primary and the nominal secondary voltage is 40 volts. How many turns would there be on the secondary?

23. A 240-volt single-phase 2.4 kVA double wound transformer has a secondary voltage of 80 volts. What is the maximum current that may be drawn from the secondary winding?

24. How much current would be drawn from the supply by a 240 volt 40 VA double wound transformer on full load?

25. A 240-volt single-phase 1.2 kVA double wound transformer has a secondary voltage of 12 volts. What is the current ratio?

26. A 240-volt single-phase 60 VA double wound transformer has a secondary voltage of 6 volts. What is the turns ratio?

27. What instrument must be used to measure the insulation resistance between the primary winding and the secondary winding of a double wound transformer?

28. A 240-volt single-phase double wound transformer has 400 turns on the primary, giving a secondary voltage of 60 volts. The PRIMARY winding is tapped at 360 and 380 turns. What would be the output voltage if the supply was connected to the 380 turn tapping?

<u>ANSWERS PAGE 229</u>

3.2 - Single-phase Split-phase Motors

1. There are several different types of single-phase motor, the most common of which are:

    a. Split-phase motors.
    b. Capacitor start motors.
    c. Capacitor start, capacitor run motors.
    d. Permanent capacitor motors.
    e. Shaded pole motors.
    f. Series universal motors.

2. The first four motors in the list above are induction motors which operate on what is known as the 'split-phase principle' and are similar in construction. Shaded pole and series universal motors operate on different principles and will be covered separately.

3. Single-phase induction motors typically range in size from about 10 watts to several kilowatts, but motors above about 3 kW are relatively rare, due mainly to the high starting current required.

Split-phase Type Motor Construction

4. An exploded view of a typical single-phase split-phase induction motor is shown in Figure 1.

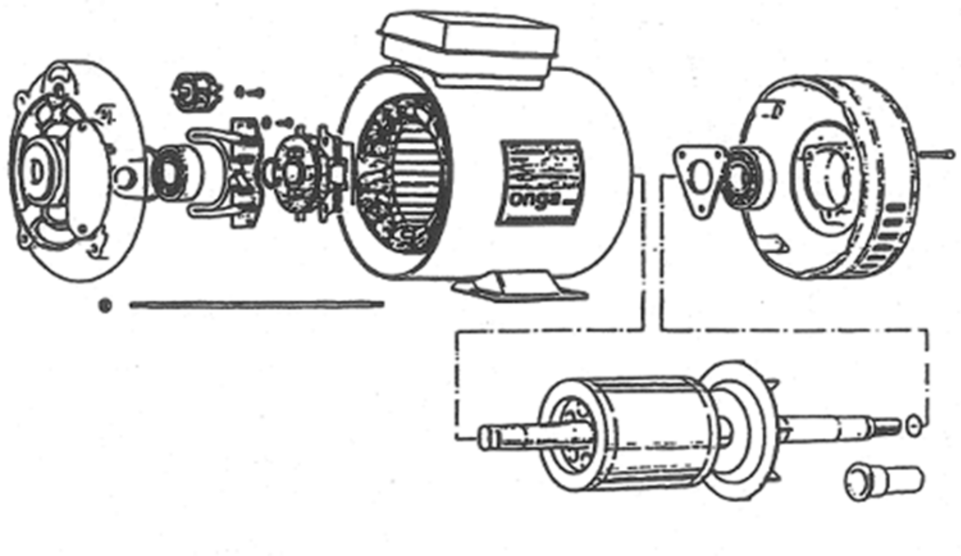


Figure 1 - Typical split phase induction motor

Drawing © North Metropolitan TAFE

5. The stator core of a typical split-phase type motor is made up of a stack of laminations with semi-enclosed slots. The wound poles are made up of three or four series-connected coils wound in concentric gangs as shown in Figure 2 - one gang for each magnetic pole.

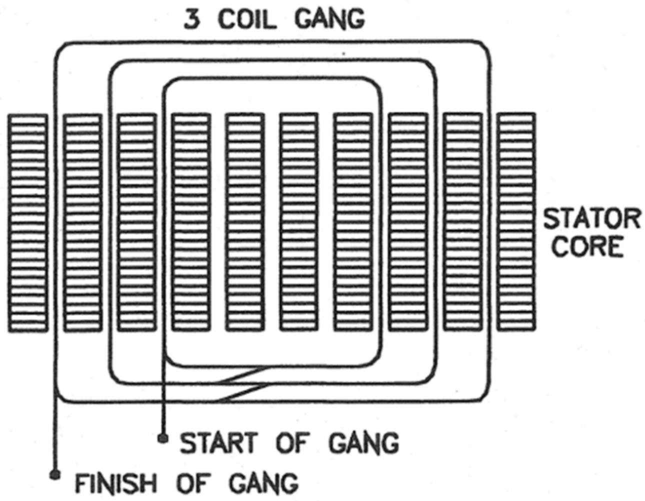


Figure 2 - Concentric coils wound in a gang

6. There are two completely separate groups of coils - one group is known as the RUN winding and the other is known as the START (or auxiliary) winding, and the number of coils in each group must be the same. The number of gangs of coils connected in series for each group determines the number of magnetic poles in the stator. The physical position of the gangs of coils in the start and run windings in a 4 pole split-phase motor are shown in Figure 3.

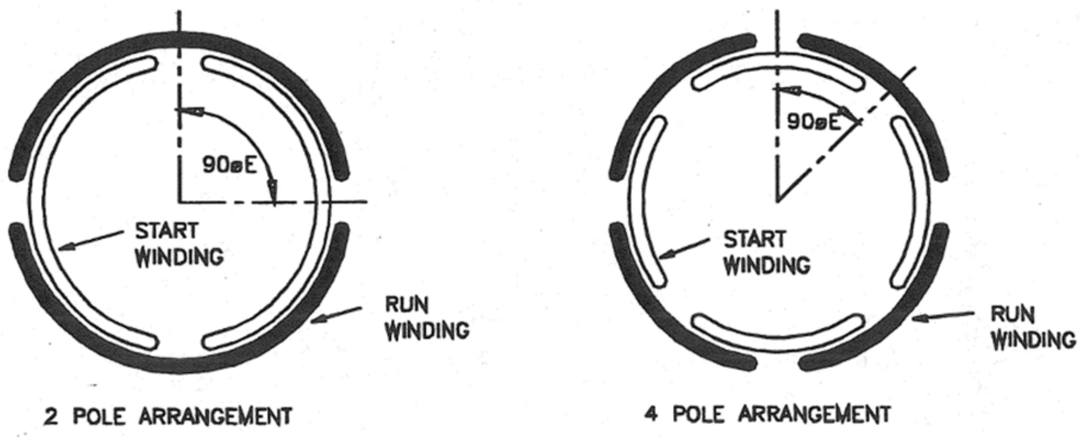


Figure 3 - Position of the start and run windings

Drawings © North Metropolitan TAFE

7. The start and run windings have different electrical characteristics and they are positioned in the stator so that each adjacent gang of coils is 90 electrical degrees apart. (360 electrical degrees is defined as the number of degrees from the centre of one pole to the centre of the next adjacent pole of the same polarity.)

8. The run winding consists of many turns of a relatively large diameter insulated winding wire and is placed in the slots first. The start winding consists of fewer turns of a relatively small diameter wire and is placed in the slots so that it sits on top of the run winding (with sheet insulation between the windings).

9. Since the run winding is deeper in the slots it has more inductance than the start winding, and since it is wound with a larger diameter wire it usually has a lower resistance than the start winding. Since the start winding is higher in the slots it has less inductance than the run winding, and since it is wound with a smaller diameter wire it usually has a higher resistance than the run winding.

10. Typical values of resistance in a 4 pole 180 watts split-phase type motors are about 8-10 ohms for the run winding and about 10-12 ohms for the start winding.

Squirrel Cage Rotor

11. A typical squirrel cage rotor consists of comparatively large bars of conducting material (usual aluminium) cast into the slots in the rotor and joined at each end of the rotor with conducting 'end rings'. No insulation is necessary between the rotor bars and the laminated steel rotor core because the rotor winding has a much lower resistance than the rotor core. An outline of the construction of a typical squirrel cage rotor is shown in Figure 4, but you should bear in mind that rotor bars and end rings can have other shapes and they can be made from other materials(such as copper).

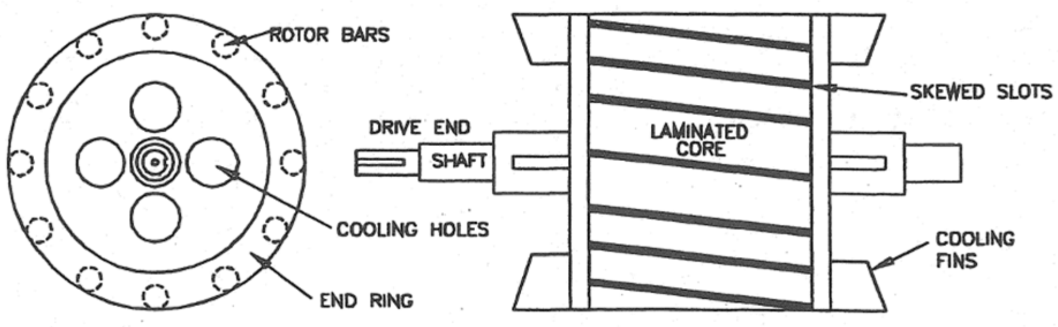


Figure 4 - Basic construction of a squirrel cage rotor

12. Most split-phase type motors require a mechanism to disconnect the start winding when the rotor reaches about 75% of full speed. The most common method of disconnecting the start winding is a centrifugal switch mechanism part of which is on the rotor and part attached to the inside of the non-drive-end end shield. The switch mechanism is closed when the motor is stationary.

13. In single-phase split-phase type motors in which it is undesirable to have a starting switch built into the motor, such as in a sealed unit refrigerator, electromagnetic or thermal starting switches are used.

The Split-phase Motor Principle

14. In a typical split-phase motor the start and run windings are connected in parallel across the single-phase a.c. supply and a centrifugal switch are connected in series with the START winding as shown in Figure 5.

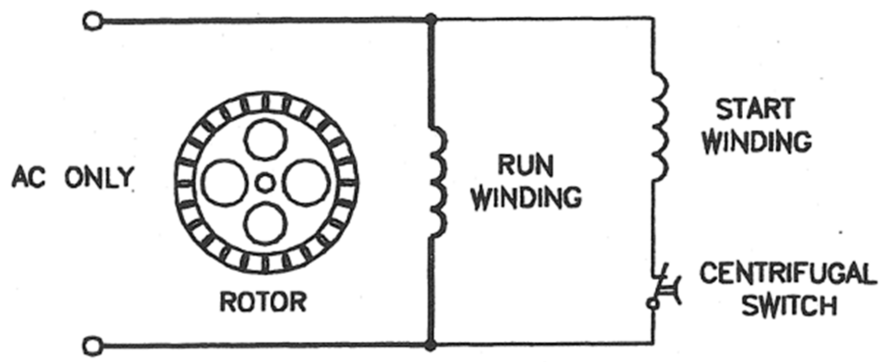


Figure 5 - Typical split-phase motor connection.

15. The coil groups in each winding are connected so that magnetic poles will be formed on the stator. The polarity of the poles changes for every half cycle of the input voltage and the polarity of the run winding poles in relation to the start winding poles will depend on the direction of current at that instant. Figure 6 shows a simplified representation of typical relative polarities of the poles in a 2 pole stator at a given instant.

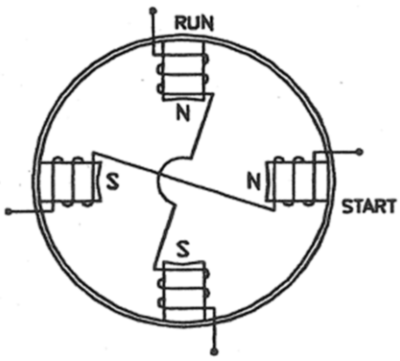


Figure 6 - Magnetic poles on the stator at a given instant.

Drawings © North Metropolitan TAFE

16. The start and run windings are both inductive so the current in both of them lags the applied voltage. However, the run winding is embedded deep in the stator slots so it is more inductive, so the current in the run winding lags the voltage by more than the current in the start winding. The precise angles of lag depend on the design of a particular motor, but the general relationship between the currents and the applied voltage can be shown on a phasor diagram such as the one shown in Figure 7.

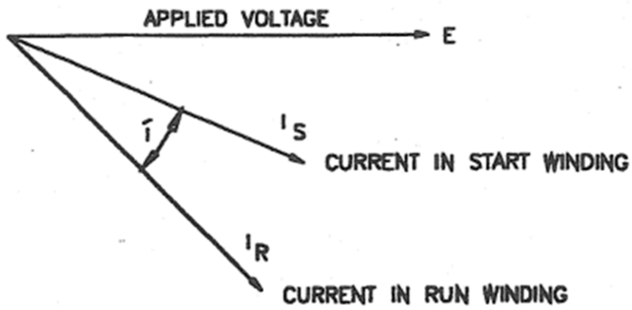


Figure 7 - Phasor diagram of current in the start and run windings.

Drawing © North Metropolitan TAFE

17. The phase angle between the current in the start and run windings in a split-phase motor is typically 20-30 degrees, and it is this 'split' that gives rise to the name 'split-phase motor.

18. The currents in the start and run windings are always out of phase, but since the supply voltage changes polarity every half cycle, the polarity of each of the poles changes every half cycle also. The continuing change of polarity results in the axis of the combined start and run winding fluxes moving around the stator at what is known as 'synchronous speed'. The direction of the single-phase 'rotating' field depends on the relative polarity of the start winding flux compared to the run winding flux.

19. As the combined 'rotating' field sweeps past the conductors in the squirrel cage rotor a current is induced in the rotor winding which reacts with the stator flux and the rotor moves in the same direction as the rotating magnetic field. The rotor rotates at a speed that is determined by the number of poles on the stator, the frequency of the supply and the amount of load. The rotor can never rotate at synchronous speed or above (unless it is driven mechanically) because at synchronous speed there would be no relative movement between the rotating magnetic field and the rotor, so no current would be induced in the rotor. The difference between synchronous speed and rotor speed is known as 'slip'.

20. When the rotor reaches a speed of about 75% of synchronous speed the normally closed centrifugal switch opens and disconnects the start winding. The start winding has a very short time rating - if it remains connected in the circuit for more than about 30 seconds it will probably burn out.

21. The full load speed is determined by the amount of slip - a typical value of slip is 4-5%. Full load speed can be calculated as follows.

22. Example Find the full load speed of a 240 volt 50 Hz single-phase 4 pole split-phase motor if the slip is 4%.

$$N_{syn} = \frac{f \times 120}{P}$$

$$N_{syn} = \frac{50 \times 120}{4}$$

= 1500 r/m

Slip = 4% of 1500

= 60 r/min

Full load speed = 1500 – 60

= 1440 r/min

23. The full load current is governed by the design of the motor. A typical 240 volts 180 watts 50 Hz single-phase split-phase induction motor has a full load current of around 2.2 amps and a no-load current of around 2 amps. Since an induction motor operates on a.c., Ohm's Law does not apply in the same way as it does in d.c. circuits, therefore the line current cannot be calculated by dividing the power rating by the applied voltage.

24. To reverse the direction of rotation of a split-phase motor it is necessary to reverse the direction of current in the start or the run winding (but not both); this can be done by reversing the connections to either the start or the run winding (while the motor is isolated from the supply).

25. The starting torque of a split-phase motor is relatively low because of the phase difference between the current in the stator winding and the current in the rotor winding. A typical characteristic curve for a split-phase motor is shown in Figure 8.

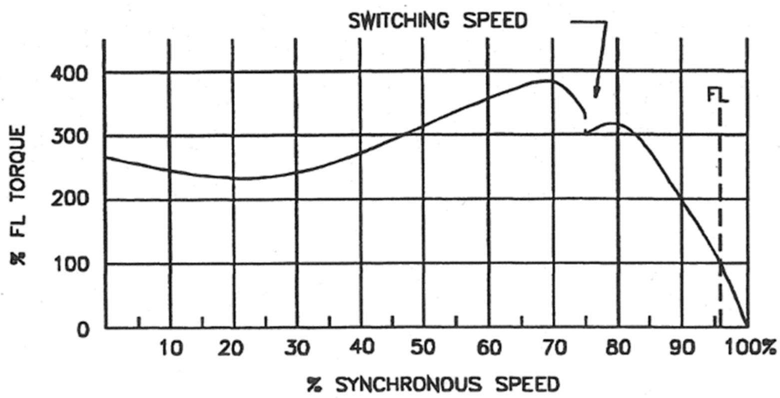


Figure 8 - The Typical characteristic curve of a split-phase motor

26. Split-phase motors do not develop enough starting torque to start heavy loads; they are mainly used in devices that do not require high starting torque such as washing machines, blowers and small bench grinding machines. The efficiency of split-phase type motors is lower than three-phase induction motors of the same size - typically around 60%.

Capacitor Start Motor

27. The starting torque of a split-phase type motor can be improved by increasing the phase angle between the run winding current and the start winding current. This can be achieved by connecting a suitable capacitor in series with the START winding - the motor is known as a Capacitor-Start motor. A circuit diagram of the connections and a phasor diagram of the relationship between the currents in a typical capacitor start motor is shown in Figure 9.

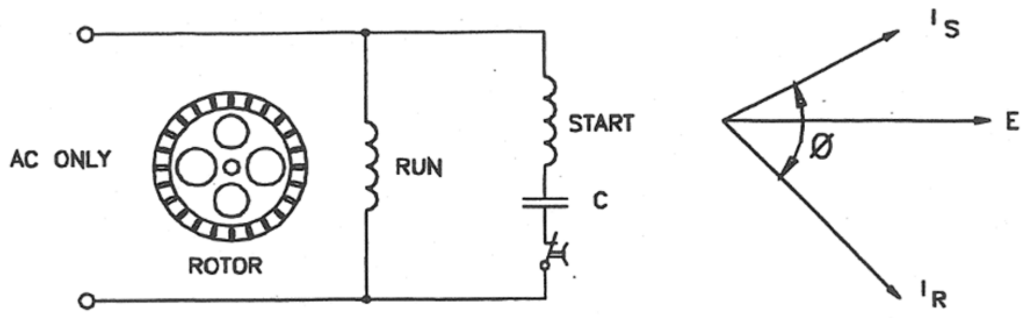


Figure 9 - Phase relationships in a typical capacitor start motor

28. A capacitor start motor has the same size and type of run winding as an equivalent size split-phase motor, therefore their running characteristics would be identical, but the start winding is wound with a larger diameter winding wire (so it usually has a lower resistance than the start winding of an equivalent split-phase motor).

29. A typical characteristic curve for a split-phase motor is shown in Figure 10. The starting torque can be up to about 2.5 times the starting torque of an equivalent split-phase motor - depending on the capacitor chosen by the manufacturer.

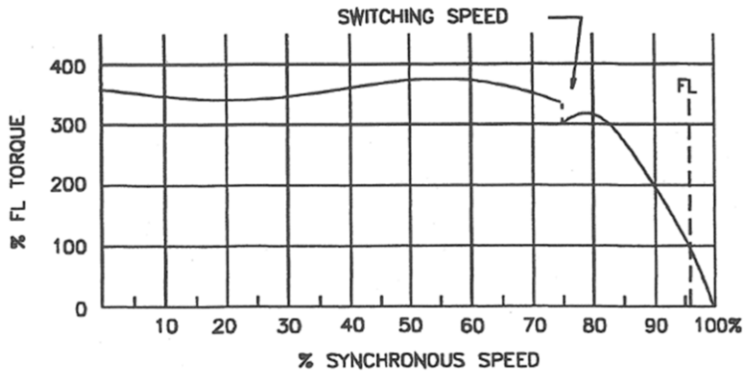


Figure 10 - Typical characteristic curve of a capacitor start motor

Drawings © North Metropolitan TAFE

30. The capacitor in a 180-watt capacitor start motor is typically a special electrolytic motor starting capacitor of about 150 microfarads and it is usually mounted on the outside of the motor carcass Some manufacturers use two capacitors mounted inside the end- shield. Since the capacitor is in series with the start winding, it is not subjected to the full supply voltage, so some manufacturers use capacitors with a voltage rating below 240 volts RMS.

31. The direction of rotation of a capacitor start motor can be reversed in the same way as for a split-phase motor - by reversing the connections to either the start or the run winding (while the motor is isolated from the supply).

32. Capacitor start motors are mainly used where a high starting torque is required, such as in refrigeration compressors and air compressors.

33. Some capacitor start motors may have a limited number of starts per hour, for example, 20 three second starts per hour.

34. Although most general-purpose split-phase type motors have a centrifugal switch, disconnection of the start winding can be achieved using other methods such as:

a. **An electromagnetic** mechanism that opens the start winding circuit when line current falls to a specified value during starting. On starting, heavy current flows in the run winding, pulling a plunger up to connect the start winding. As the motor speeds up the current fall to about 70% of full speed, the plunger is released and the contacts open, disconnecting the start winding. A circuit showing the principle is shown in Figure 11.

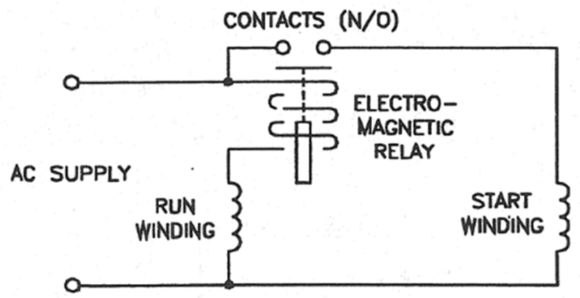


Figure 11. - Electromagnetic starting switch principle.

Drawings © North Metropolitan TAFE

b. **A thermal mechanism** that opens the start winding circuit when the starting current has heated a bi-metal strip to a pre-set value.

c. **An electronic timing mechanism** is placed in series with the start winding and open-circuits the winding at a pre-set time, usually less than one second after the motor has been connected to the supply.

Capacitor Start-Capacitor Run Motor

35. Capacitor start capacitor run motors are similar in operation to the capacitor start motor except that they have another capacitor permanently connected in series with the start winding, in addition to the starting capacitor as shown in Figure 12. Various centrifugal switch connection arrangements are possible.

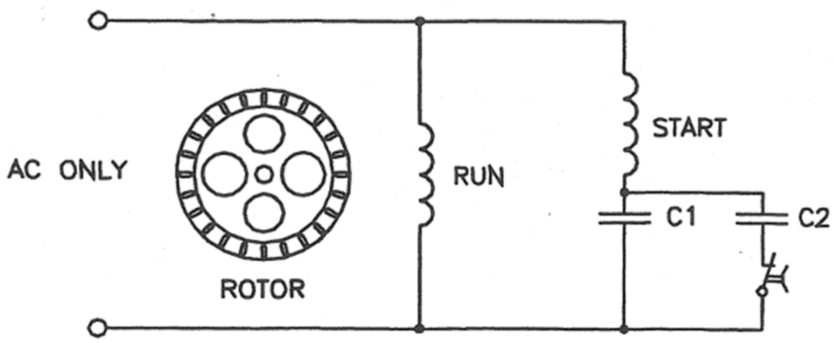


Figure 12 - Capacitor start capacitor run motor connections.

36. The two capacitors in parallel during starting provides good starting torque, while the running capacitor provides good running torque, better overload capacity, better efficiency, better power factor and quieter operation. The capacity of the running capacitor is usually lower than that of the starting capacitor (usually less than 20 μF). The two capacitors must be connected in the circuit correctly as they are designed for different purposes. In Figure 12, the starting capacitor (C2) is a non-polarised Aluminum Electrolytic capacitor (usually greater than 70 μF) and is only designed to be energised for a short time. The Run capacitor (C1) is a polypropylene film capacitor and is designed for continuous duty.
This type of motor is widely used for driving refrigerator compressors.

37. The direction rotation of a capacitor start capacitor run motor can be reversed by reversing the connections to either the start or the run winding, but not both.

Permanent Capacitor (PSC) Motor

38. A permanent capacitor motor has the same type of winding arrangement as a capacitor-start motor, but the 'start' winding is designed to remain permanently connected, as shown in Figure 13, so no centrifugal switch mechanism is required. Both windings are identical, and the 'start' winding is usually referred to as the auxiliary winding.

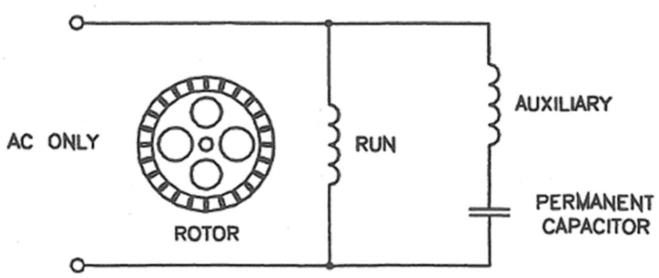


Figure 13 - Permanent capacitor motor connections.

39. The starting torque in a permanent capacitor motor is low compared to capacitor start motors. They are widely used in small fans (up to about 120 W), and they are well suited to variable speed operation such as in multi-speed air conditioner fans where the speed can be varied by varying the capacitance of the capacitor.

40. The direction rotation of a permanent capacitor motor can be reversed by reversing the connections to either the run or the auxiliary winding, but not both. Another method of reversing a permanent capacitor motor is to change the phase angle in one winding relative to the other by connecting a permanent capacitor as shown in Figure 14. This method is commonly used in motors associated with the regulation of air flow in air conditioning systems.

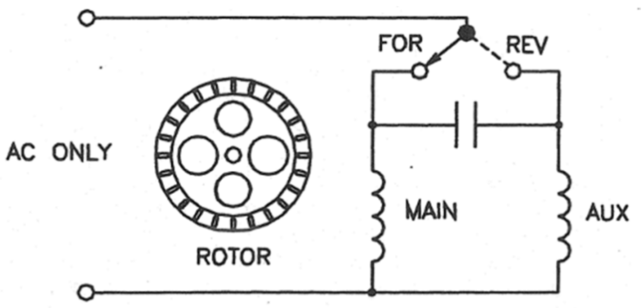


Figure 14 - Arrangement for reversing a permanent capacitor motor.

Drawings © North Metropolitan TAFE

Motor Testing

41. The most common faults which occur in electric motors are short circuits, open circuits and insulation resistance faults. In split-phase type motors which incorporate a switching mechanism to disconnect the starting winding, the contacts on the switch can weld together causing the start winding to overheat and burn out.

42. Before you connect a motor to the supply you need to accurately identify the ends of the electrical components. The most suitable instrument to use is a multimeter set to the ohms x 1 range. The connections at the terminal block should be disconnected during the test to avoid any unwanted parallel connections.

43. The start or auxiliary winding is usually the one with the highest d.c. resistance - typically 10-12 ohms for a 180-watt split-phase motor. The resistance will be less for a larger motor or a capacitor type motor. If the resistance of a winding is zero ohms it indicates a short circuit. A resistance of infinity indicates an open circuit.

44. The run winding usually has a resistance of about 8-10 ohms for a 180-watt split-phase motor, or less for a larger motor.

45. The resistance of the normally closed centrifugal switch should be zero ohms when measured with a multimeter.

46. The capacitor can usually be tested or identified by noting that the multimeter resistance reading goes up-scale on a high ohms range, then slowly moves downscale to the infinity position (as the battery in the multimeter charges the capacitor). If the multimeter indicates around zero ohms it indicates that the capacitor is short-circuited. If it indicates infinity ohms without moving, it indicates that the capacitor is open-circuited.

47. If a split-phase motor is tested for winding resistance with all connections correctly made, the resistance reading should be the equivalent resistance of the run winding and the start winding connected in parallel. If a capacitor type motor is tested the resistance reading would be the resistance of the run winding alone because the capacitors would be virtually equivalent to an open circuit.

48. In split-phase type motors, the start winding usually has a higher resistance than the run winding, but this is not always the case, particularly in capacitor start motors. To avoid permanent damage to the motor resulting from incorrectly connecting the run winding in series with the centrifugal switch you should always run a newly connected motor for a few seconds on no load and check the line current. It should be LESS than the value shown on the nameplate. If it is not, you could have the start winding connected directly across the supply.

49. Short circuits between turns in a winding can be detected with an internal growler the motor must be dismantled for this test, and any parallel connections must be disconnected.

50. The insulation resistance between windings and from each winding to earth (or frame) must be measured with a 500-volt high voltage insulation tester (a Megger). The minimum permissible insulation resistance is 1 megohm, but most single-phase motors should have an insulation resistance greater than 200 Megohms.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 1	Summary Questions 3-2	Version 4 2021

Single-phase Split-phase Type Motors

1. How can a single-phase split-phase stator winding be distinguished from a 3 phase winding of about the same power rating?

2. What type of rotor do ALL split-phase type motors have?

3. How many windings does a single-speed capacitor start motor has and what are they usually called?

4. What component do most single-phase split-phase induction motors have that three-phase squirrel cage induction motors do not have?

5. What is the most common operating voltage for split-phase and capacitor start motors in W.A.?

6. What is a typical full load current rating of a 0.18 kW, 240-volt single-phase split-phase or capacitor-start motor?

7. When a single-phase split-phase type motor is stationary, is the centrifugal switch open or closed?

8. How can the direction of rotation of any split-phase type motor be reversed?

9. What is the only component in a split-phase or capacitor start motor that can safely be connected so that it is in PARALLEL with the supply when the motor is running on full load?

10. Is the resistance of the start winding higher or lower than the resistance of the run winding in a typical split-phase type motor?

11. What are the two most common positions for the capacitor(s) in a capacitor start motor?

12. What component is connected in series with the start winding in a split-phase type motor?

13. If the resistance of a start winding in a split-phase motor is 12 ohms, and the resistance of the run winding is 6 ohms, what would be the resistance between the line terminals if the motor was stationary?

14. What does the centrifugal switch do when a capacitor start motor reaches about 75% of full speed?

15. What is a typical full load speed for a 4 pole 50 Hz single-phase split-phase or capacitor to start the motor?

16. What are the two major differences between a split-phase motor and a capacitor start motor?

17. Draw a circuit diagram of a typical 240-volt single-phase split-phase motor. Label all components and show a typical resistance for each component.

18. Draw a circuit diagram of a typical 240-volt single-phase capacitor start motor. Label all components and show a typical resistance for each component.

19. List four common types of single-phase split-phase type motor.

20. Which electrical component in a capacitor start motor has the LOWEST resistance?

21. What is the name given to the speed of the 'rotating' magnetic field in an induction motor?

22. What is the advantage of a capacitor start motor compared to a split-phase motor of the same power rating?

23. How can the direction of rotation of a single-phase capacitor start motor be reversed?

24. What is the function of the centrifugal switch in a single-phase capacitor start motor?

25. What effect will it have on the operation of a split-phase motor if the start winding remains connected when the motor is running at full speed?

26. The total measured resistance of a particular **split-phase** motor is 4.8 ohms and the Run winding is 8 ohms. Calculate the value of resistance of the Start winding.

27. What type of starting capacitor is usually used in a modern capacitor start motor?

28. What is a typical value of capacitance for the starting capacitor in a typical 180-watt capacitor start motor?

29. In what unit is the starting torque of an electric motor usually expressed?

30. The run winding of a particular **capacitor start** motor has a resistance of 8 ohms and the start winding is 12 ohms. What value of resistance would be measured between the incoming active and neutral (with the supply disconnected)?

31. What effect will it have on the operation of a split-phase motor if the centrifugal switch fails to operate correctly?

32. Refer to the following page of single-phase motor circuits.
What type of motor is shown in Figure A?

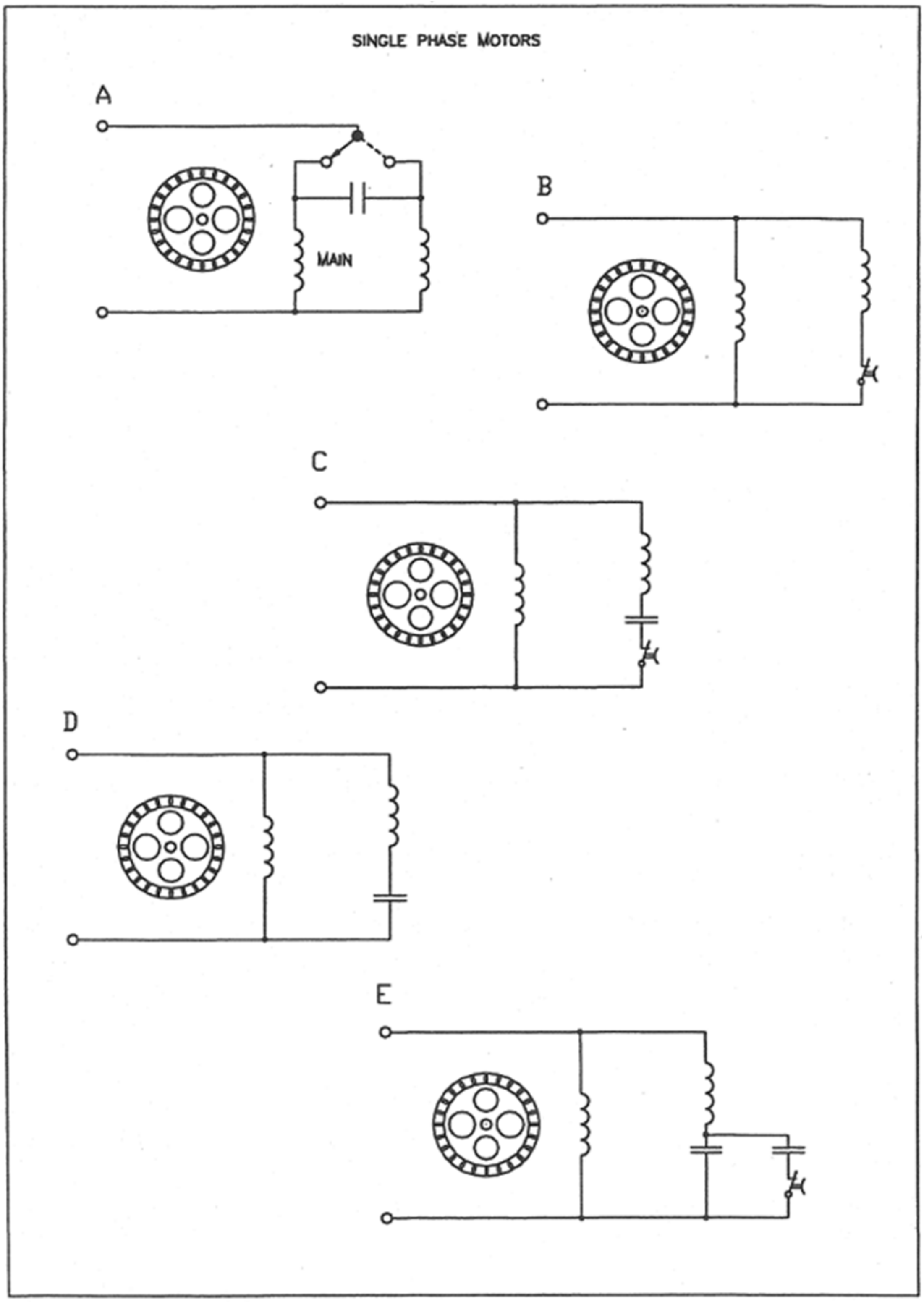
33. Refer to the following page of single-phase motor circuits.
What type of motor is shown in Figure B?

34. Refer to the following page of single-phase motor circuits.
What type of motor is shown in Figure C?

35. Refer to the following page of single-phase motor circuits.
What type of motor is shown in Figure D?

36. Refer to the following page of single-phase motor circuits.
What type of motor is shown in Figure E?

ANSWERS PAGE 231



Drawing © North Metropolitan TAFE

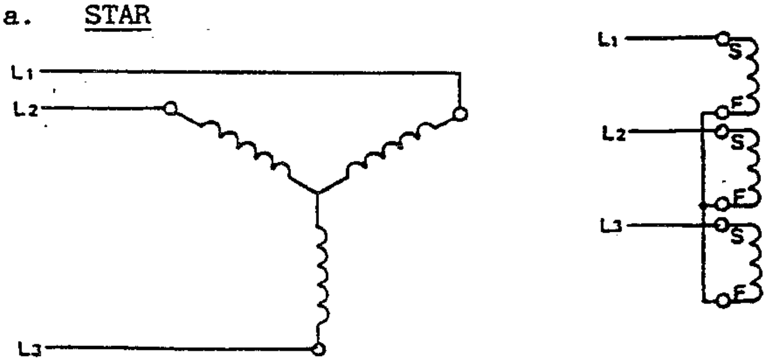
North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 3	3-3	2021

3.3 - Three-phase Transformers

Winding Configurations

15. Three-phase transformers can be connected in various STAR-DELTA configurations to give different output voltages. Care must be taken to connect the starts and finishes of windings correctly. Incorrect connections can give unequal voltages, producing circulating currents that could result in the transformer burning out.

a. STAR

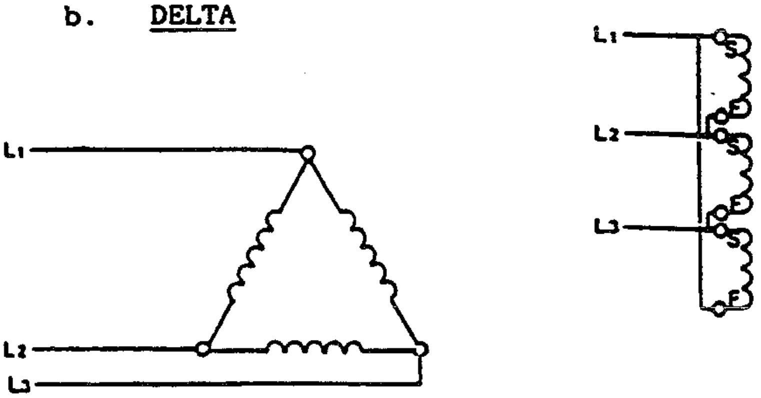


Line I = Coil I

Coil V = $\frac{\text{Line V}}{\sqrt{3}}$

Line V = Coil V x $\sqrt{3}$

b. DELTA



Coil I = $\frac{\text{Line I}}{\sqrt{3}}$

Line I = Coil I x $\sqrt{3}$

Line V = Coil V

Drawings © North Metropolitan TAFE

16. It is important to remember the basic star and delta connections and the relationships between line and coil voltages. It is from these that calculations for voltage and turns ratios are based.

17. For three-phase transformers, it is the relationship between the primary and secondary COIL voltages (Coil V) that determine the voltage and turns ratios, NOT the input and output line voltages (Line V).

18. The four common methods of connecting the primary and secondary windings of three-phase transformers are:

    1. STAR - STAR
    2. DELTA - DELTA
    3. DELTA - STAR

4. STAR - DELTA

19. Whichever configuration is used the output line voltages can be calculated, given the voltage or turns ratio and the input line voltage.

20. When the windings of a three-phase transformer are connected in either star or delta, the voltage and current in each phase winding should be the same. If the voltages are not equal, one of the coils must be reversed.

Examples:

A 400V three-phase transformer has 200 turns on the primary windings and 40 turns on the secondary windings. Find the output voltages for each of the connection methods.

STAR – STAR

(Star P) Line V = 400V

$$\text{Coil V} = \frac{400}{\sqrt{3}} = 230 \quad (=V1)$$

$$\frac{V1}{V2} = \frac{N1}{N2} = \frac{200}{40}$$

$$V2 = \frac{V1.N2}{N1} = \frac{230 \times 40}{200}$$

= **46V** = (Coil V)

(Star S) Line V = √3 x Coil Voltage

= √3 x 46 = **80V**

DELTA -DELTA

(Delta P) Line V = Coil v = 400V (=V1)

$$\frac{V1}{V2} = \frac{N1}{N2} = \frac{200}{40}$$

$$V2 = \frac{V1.N2}{N1} = \frac{400 \times 40}{200}$$

= 80V = (Coil V)

(Delta S) Line V = Coil V = **83V**

DELTA – STAR

(Delta P) Line V = Coil v = 400V (=V1)

$$V2 = \frac{V1.N2}{N1} = \frac{400 \times 40}{200}$$

= 80V = (Coil V)

(Star S) Line V = √3 x Coil Voltage

= √3 x 80 = **138.6V**

STAR – DELTA

(Star P) Line V = 400V

$$\text{Coil V} = \frac{400}{\sqrt{3}} = 230 \quad (=V1)$$

$$\frac{V1}{V2} = \frac{N1}{N2} = \frac{200}{40}$$

$$V2 = \frac{V1.N2}{N1} = \frac{230 \times 40}{200}$$

= 46V = (Coil V)

(Delta S) Line V = Coil V = **46V**

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-3	Version 4 2021

Three-phase Transformers

1. Draw a circuit diagram of a three-phase transformer connected to STAR-DELTA. Clearly label the primary and secondary windings and show all terminal markings.

2. A three-phase step-down transformer is connected to DELTA-STAR. If the input line voltage is 400 volts and the turn's ratio is 5:1, what is the output line voltage?

3. What precaution must be taken before permanently connecting the primary or secondary coils of a three-phase transformer in DELTA?

4. Which winding in a three-phase 400:24 volt step down transformer should have the highest resistance?

5. What fault is indicated (if any) if the voltage at the closing connection of the primary of a delta connected three-phase transformer is twice the normal input line voltage?

6. What size and type of test instrument should be used to check the insulation resistance to earth and between windings in a 400:110 volt three-phase transformer? What is the minimum permissible resistance?

7. Which type of core construction is mainly used for three-phase transformers?

8. Show, with a simple diagram, how three single-phase transformers can be connected into a three-phase configuration.

9. A three-phase transformer with a transformation ratio of 20:1 is connected to an 11 000 V supply. What line voltage would appear across the output terminals when the transformer is connected?

   a. Star - Delta
   b. Delta - Star

10. What is the maximum output line current, and coil current, of a 50 kVA DELTA connected three-phase transformer, if the output LINE voltage is 400 V?

<u>ANSWERS PAGE 232</u>

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Summary 3-4	Version 4.1 2021

3.4 - Transformer Testing

1. Any transformer must be inspected and tested to verify that the transformer complies with the Australian Standard AS2374.

2. The recommended inspection and testing sequences for low voltage transformers are as follows:-

3.

a. Visual Inspection - Many defects may be present in a transformer that cannot be discovered by testing with instruments.

Some examples are
i) Loose laminations
ii) Oil leaks (in oil-filled transformers)
iii) Loose terminals
iv) Condition of windings
v) Condition of supports and mounting
vi) Overheating on no-load condition

b. Continuity of all Windings - A continuity tester is used to check that a conductor is continuous along the whole of its length. The ohmmeter, which is used for determining the resistance value, will serve as a continuity tester.

c. Insulation - Insulation resistance is measured with a 500-volt high insulation resistance tester (Megger) for winding voltages not exceeding 250 V to earth and must be no less than the minimum value allowable according to the Wiring Rules.

Check all conductors both primary and secondary are electrically insulated from the metal frame or core.

Check insulation resistance between all primary and secondary windings of the transformer.

d. Primary and Secondary Identification -From the given transformer information the primary and secondary can be identified as follows:

i) Step down double wound transformer

With an ohmmeter measure the d.c. resistance of each winding. The resistance will be higher in the primary winding.

ii) Step up double wound transformer

The d.c. resistance will be higher in the secondary winding.

e. Overheating -Could indicate shorted turns in the windings caused by circulating currents around the shorted turns. Check the d.c. resistance of all windings and compare with manufacturers data.

Faults and Testing

3. The four main faults that can occur in transformers in service are:

   a. Earth faults: where insulation failure results in a winding or connection shorting to earth. Usually caused by faulty insulation, ingress of moisture and magnetic stress.

   b. Interwinding faults: where a breakdown of insulation results in the primary winding shorting to the secondary winding. Causes - same as in earth faults.

   c. Shorted turns: where adjacent turns short together. Mainly due to conductor insulation breakdown caused by overheating, due to overload and poor ventilation, or coil movement resulting from magnetic stress.

   d. Open circuit: where a faulty connection, or joint, breaks the continuity of the windings. Usually caused by poorly made connections or dry joints.

Transformer Testing

4. The following basic tests can be carried out to identify faults within a transformer

   a. Earth faults: This test is carried out with a High Voltage Insulation resistance tester (Megger) set at 500 volts. The test is conducted from each winding terminal to the metal frame (Earth) of the transformer. The readings should be within specified limits, usually not less than 1 megohm.

   b. Interwinding fault: A Megger is used again to test between, both primary and secondary windings as well as between all phases.

   c. Continuity of Windings (Shorted Turns/Open Circuit): An ohm meter (on ohms scale) is used to check the continuity of all the windings. On a three-phase transformer, a comparison between each of the three winding can be used as a satisfactory result (both for primary and secondary windings). Whereas with a single-phase transformer the manufactures specification would be required to determine the accuracy of the results for both primary and secondary windings.

   d. Earth Continuity: If the transformer is housed in a metallic enclosure then an ohm meter would be used to prove the iron core of the transformer is appropriately earth the frame (enclosure). The reading should be very low ohms (eg 0.5 Ω).

Wiring Rules

5. AS/NZS 3000 clause 4.14 (Transformers) contains the general requirements for transformers. where clauses 4.16 provides the requirements of equipment containing liquid dielectrics. (such as distribution transformers).

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-4	Version 4 2021

Transformer Testing

1. List the items to look for when carrying out a visual inspection of a transformer.

2. What is meant by the good continuity of a winding, and how is this test carried out?

3. The following results were obtained from a double wound STEP-UP transformer.

    a. One winding had a d.c. resistance of 90 ohms
    b. The other winding had a d.c resistance of 15 ohms

    Determine the primary winding and secondary winding.
    Describe one method of determining the resistance of the windings.

4. List the four main faults that could occur in a transformer when in service.

5. Describe one method of testing a transformer winding for short-circuited turns.

6. What instrument and setting are used to test for interwinding faults in a transformer?

<u>ANSWERS PAGE 233</u>

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 3	3-5	2021

3.5 - Three-phase Induction Motors Construction

Motor Enclosures

1. Electric motor enclosures are available in many different types of an enclosure to suit particular applications. There are three basic types of an enclosure with several variations of each type, but the modern trend is to concentrate on protected and enclosed types mainly.

The types are:

Enclosed

(i) Those in which there is no restriction to ventilation other than necessary for good mechanical construction (previously known as OPEN machines).

(ii) Those in which the inlet and outlet air ducts are covered with a screen of perforated or expanded mesh, the openings of which have an area of at least 0.645 square centimetres (previously known as SCREEN PROTECTED).

(iii) Those in which ventilation openings are so protected as to exclude vertically falling water or dirt (previously known as DRIP PROOF).

Enclosed This type includes:

(i) Machines constructed so that the air enclosed has no connection with the external air duct but is not necessarily 'airtight' - cooling is affected by circulating the air within the frame (TOTALLY ENCLOSED).

(ii) Machines that are enclosed, but cooling is augmented by a fan, driven by the motor itself, blowing external air over the cooling surfaces and/or through the cooling passages. The fan is covered by a cowl which is often extended to cover the motor completely to give more effective cooling (TOTALLY ENCLOSED FAN COOLED (TEFC).

(iii) A machine in which there is a continuous supply of fresh ventilating air, the frame being so arranged that the ventilating air may be conveyed to and/or from the machine via pipes or ducts (PIPE OR DUCT VENTILATED).

Flameproof

Machines designed to comply with the relevant Australian Standards for flameproof machines.

Motor Construction

2. An exploded view of a SIEMENS three-phase TEFC squirrel cage induction (SCI) motor is shown in Figure 1. Parts A to J is labelled on the diagram.

    a. Drive-end end shield
    b. Rotor and rotor winding (squirrel cage type) on a shaft.
    c. Terminal box
    d. Stator core with 415 volt 50 Hz insulated winding.
    e. Mounting feet.
    f. Bearing.
    g. Non-drive-end end shield.
    h. Main external cooling fan.
    i. Cowl for the external cooling fan.
    j. Terminal block.

3. Exercise
    Examine the exploded view in Figure 1. Label the following parts on the diagram if they are shown:

    a. Frame or carcase.
    b. Drive-end keyway.
    c. Lubrication points
    d. Supply cable entry point.
    e. Eyebolt.
    f. Pulley or drive gear (usually keyed to the shaft).
    g. Internal cooling fan.
    h. Earthing terminal.
    i. Nameplate.
    j. Bearing Housings.
    k. Bearing cap.
    l. Wave washer.
    m. Circlips.
    n. Flange mounting.

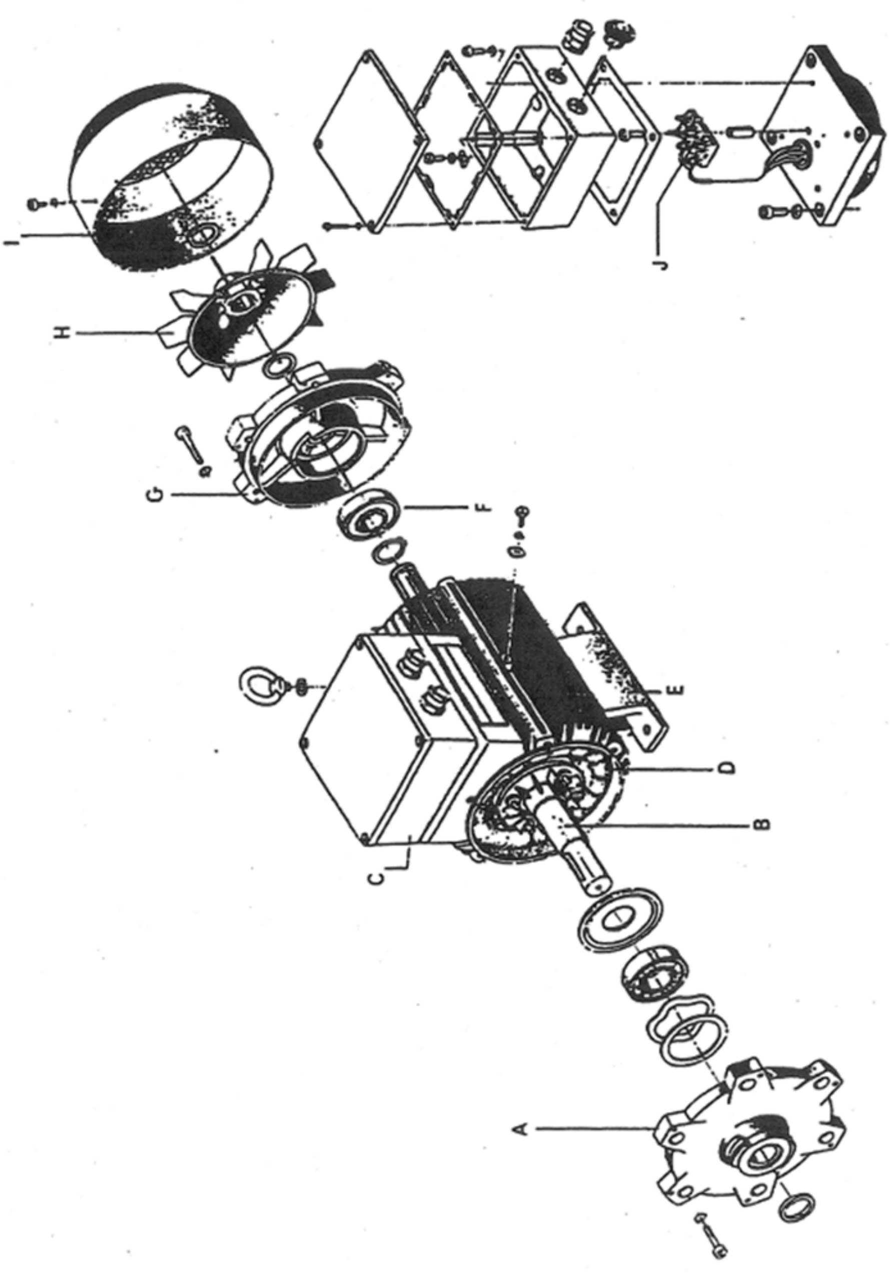


Figure 1 - Exploded view of a SIEMENS three-phase TEFC SCI motor.

Drawing © North Metropolitan TAFE

Three-phase Motor Connections

5. Two basic connections are common in three-phase squirrel cage induction motors- the STAR connection and the DELTA connection. Some motors are internally connected in either star or delta and have THREE input line terminals. Others are designed to be started in the star, then switched to delta for full load running - these have SIX line terminals. Most three-phase squirrel cage induction motors are single insulated so they must be earthed but do not require a neutral.

6. The basic star and delta connections are shown in Figure 2.

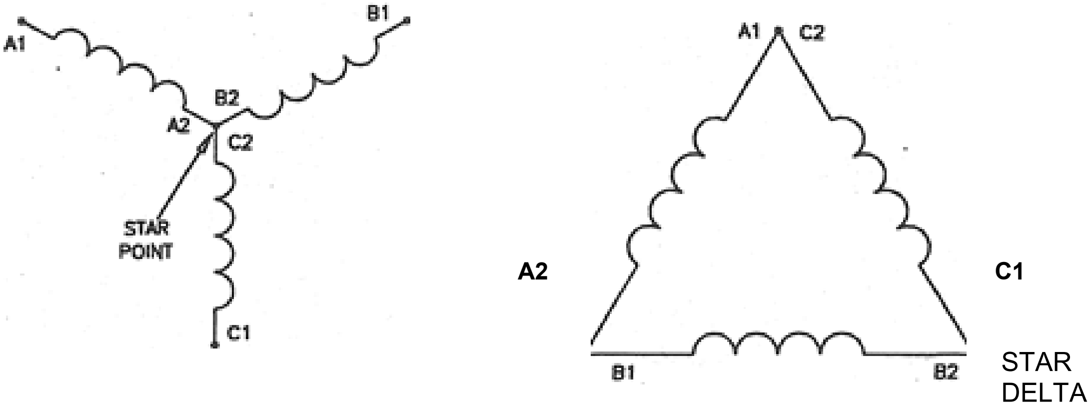


Figure 2 – The basic star and delta motor connection

7. Three Terminal Motors
These have three input line terminals on the terminal block. Typical terminal markings for the three terminals are A, B and C or U, V and W. They also have provision for earthing the frame of the motor. The three incoming line leads (L1, L2 and L3 or RED, WHITE and BLUE) are connected to the three input terminals. The European (DIN) standard markings for the terminals on a three-terminal three-phase squirrel cage induction motor are U, V and W. Figure 3 shows a typical three-terminal motor connected to the three-phase supply.

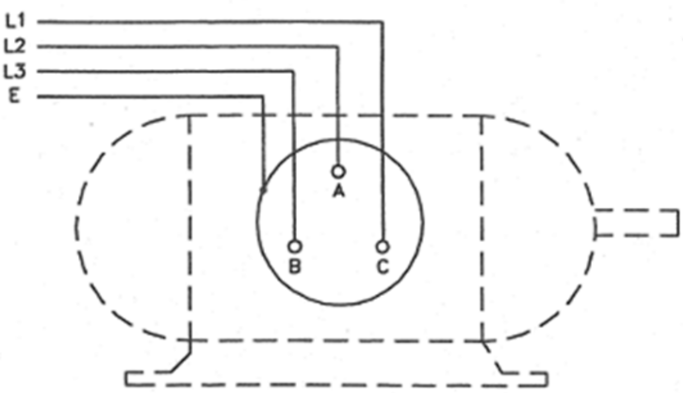


Figure 3 – Typical three-terminal motor connections.
Drawings © North Metropolitan TAFE

8. **Six Terminal Motors.**
These have six terminals connected to the stator winding. Typical terminal markings are A1, A2, B1, B2, C1, C2 (or U, V, W, X, Y, Z or U1, V1, W1, U2, V2, W2 if they are of European (DIN) origin). They are usually designed to be run in delta for a full load operation, but they can be run in star for starting or offload testing purposes.
The type of full load connection for which they have been designed should be shown on the motor nameplate. The basic star and delta connections for a typical six terminal motor are shown in Figure 4.

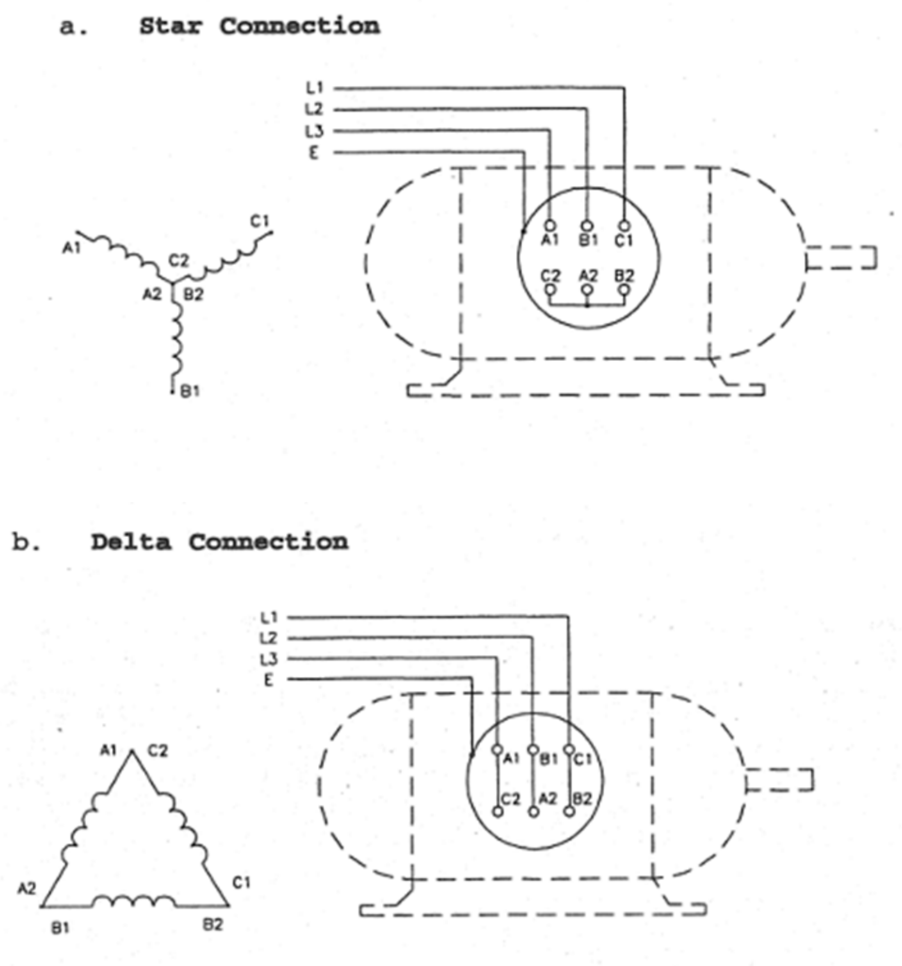


Figure 4 – Basic star and delta motor connections.

Drawings © North Metropolitan TAFE

9. You should always check the motor nameplate to make sure that the motor is suitable for the supply you are about to connect it to. Most three-phase squirrel cage induction motors in common use are designed for 415 volts, 50 Hz, but motors with other voltages may be found in special applications - particularly self-contained machinery of foreign origin.

10. All induction type motors are designed for a.c. operation only - they must not be connected to a d.c. supply unless there is a special reason (such as d.c. injection braking), in which case special additional control equipment is required.

Nameplates

11. The information on a typical electric motor nameplate includes:

    a. The manufacturer's name and the model and the serial number of the machine.
    b. The nominal voltage for which the stator winding was designed.
    c. The number of phases and the designed frequency. Three-phase motors are usually marked to indicate whether they have been designed for STAR or DELTA operation.
    d. The continuous maximum power rating of the motor in watts or kilowatts. Older motors or motors of foreign origin may have the power rating expressed in the imperial unit horsepower - 1 horsepower is equivalent to 746 watts.
    e. The maximum continuous line current the motor is designed to draw (full load current or FLC) per phase. If this full load current is exceeded the motor is said to be overloaded. If the motor starter has an overload sensing mechanism, the overloads should usually be set to the maximum current rating. the motor.
    f. The designed speed of the motor on FULL LOAD.
    g. The maximum permissible temperature rises when the motor is operating on full load.
    h. The 'class' of insulation used in the motor winding.

Operating Voltage

12. The main electrical distribution system in W.A. changed from 440/250 volts to 415/240 volts in about 1988, so there are still many motors in service with 440 volts marked, on the nameplate. Most 440 volt motors will operate satisfactorily on 415 volts and vice versa. The nominal distribution voltages for the Eastern States are 400/230 volts.

Reversal

13. To reverse the direction of rotation of a three-phase motor it is necessary to isolate the supply and swap over any two incoming supply conductors.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-5	Version 4 2021

Three-phase Motor Construction & Connections

1. List the three basic types of electric motor enclosure.
2. List 10 major parts of a three-phase squirrel cage induction motor.
3. What is the name given to the rotating component in a three-phase motor?
4. What is the name of the most common type of general-purpose three-phase motor?
5. What part of an electric motor enables details such as type, speed, current and connection to be determined?
6. What terms are used to distinguish between the two 'ends' of a typical three-phase motor?
7. What type of three-phase motor usually has a cooling fan mounted on the shaft OUTSIDE the end shield?
8. What are the two basic connections used for connecting the stator winding in a three-phase motor?
9. What is the standard line voltage for three-phase motors in W.A.?
10. What is the standard line voltage for three-phase motors in the eastern states of Australia?
11. If a standard three-phase motor is INTERNALLY connected in STAR, how many line terminals will it have at the terminal block?
12. If a standard three-phase motor is INTERNALLY connected in DELTA, how many line terminals will it have at the terminal block?
13. To which internal part of a standard three-phase motor is the line terminals connected?
14. Does a three-phase SCI motor have any electrical connections to the rotor?
15. How can the direction of rotation of a three-phase induction motor be reversed?
16. If a standard three-phase motor has SIX line terminals, would you expect it to be designed for star or delta operation on full load?
17. What are the Australian standard terminal markings on a three-terminal three-phase induction motor?
18. What are the Australian standard terminal markings on a SIX terminal three-phase induction motor?
19. Would it be safe to connect a 440 volt 50 Hz three-phase motor to a 415 volt 50 Hz three-phase supply?
20. What are the European (DIN) standard terminal markings on a standard three-terminal three-phase induction motor?
21. What are the European (DIN) standard terminal markings on a standard SIX terminal three-phase induction motor?

22. Is it permissible to terminate an earthing conductor under one of the mounting bolts used to hold an electric motor in position? Provide AS/NZS3000 clause number.

23. Does a STAR connected three-phase motor require a neutral?

24. What is the TOTAL number of conductors required to connect a typical three-phase SCI motor to the supply?

25. What is the reason that most three-phase motors must be earthed?

26. List FIVE items of information that would be found on the nameplate of a three-phase SCI motor.

27. Draw a wiring diagram showing a SIX terminal three-phase motor terminal block connected to the 415-volt mains in STAR. Label all terminals.

28. Draw a wiring diagram showing a SIX terminal three-phase motor terminal block connected to the 415-volt mains in DELTA. Label all terminals.

29. What four safety precautions must be taken before attempting to work on a typical three-phase motor that is installed with fixed wiring?

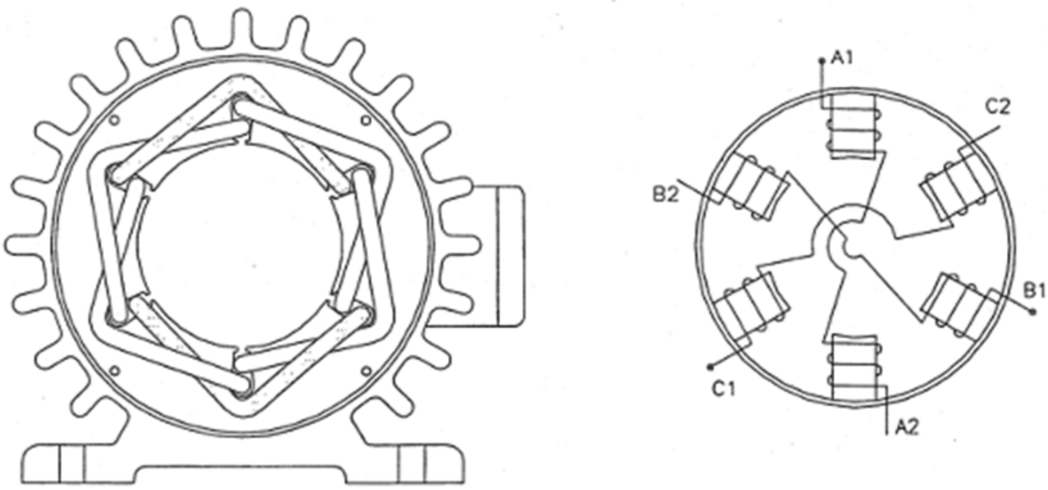
ANSWERS PAGE 234

3.6 - Three-phase Induction Motor Operation

1. A typical three-phase squirrel cage induction motor stator winding consists of a series of coils of insulated copper wire connected in such a way that magnetic poles are formed on the internal surface of the laminated stator core. The winding for each of the three phases is usually identical, but the method used to place them in the stator slots is such that the coils associated with each phase are not readily identifiable (this is known as a 'distributed' stator winding).

2. The coils associated with each phase are usually connected in series so that each phase winding forms an identical even number of magnetic poles on the internal surface of the laminated stator core. The number of poles formed on the stator core (per phase) is a major factor in determining the no-load speed of the motor. The three windings are physically positioned so that they are at 120 electrical degrees to each other, and they are usually referred to as the A phase, the B phase and the C phase.

3. A two-pole three-phase squirrel cage induction motor stator winding usually has six sets of coils (two for each phase). A simplified diagram of a two-pole stator winding is shown in Figure 1. The coils are internally connected so that the two coils associated with each phase form magnetic poles of opposite polarities on opposite sides of the stator core.



Arrangement of coils   Simplified connection diagram

Figure 1 – Simplified two-pole stator winding coil arrangement

Drawings © North Metropolitan TAFE

4. In a six terminal motor the six ends of the coil groups are brought out to the terminal block, in a three-terminal motor appropriate coil group ends are connected internally in star or delta, and three leads are brought out to the terminal block.

5. When a three-phase supply is connected to the stator winding the continually changing applied voltage results in groups of magnetic poles being formed in a particular sequence on the internal surface of the stator; the magnetic field of each coil group combines with the two others to form one overall north pole and one overall south pole (for a two-pole machine). If the machine is designed for four poles, four overall poles would be formed.

The Rotating Magnetic Field

6. Since the three-phase a.c. the supply voltage is continually changing in both magnitude and direction the polarity and strength of the resulting magnetism is continually changing. The continually changing magnetic field resulting from the changing current in the coils causes the axis of the two main magnetic poles to move at a constant rate around the inside of the stator core. This changing magnetic field is known as the ROTATING MAGNETIC FIELD (RMF).

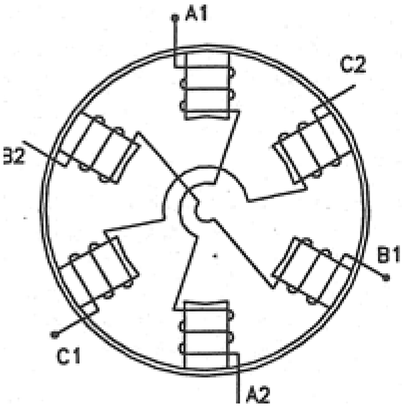
7. One method of showing how the rotating magnetic field is produced in a two-pole three-phase stator winding is shown in Figure 2. A simplified representation of the stator connections is shown beside one complete cycle of the line currents from a three-phase supply. The portions of the sine wave above the horizontal axis are assumed to represent currents flowing into the winding, and the portions below represent current flowing out of the winding. The six numbered vertical lines indicate the instant in time depicted by the six diagrams of the stator which have corresponding numbers.

8. For this explanation, the current flowing INTO a stator coil (as indicated by the small arrows) is assumed to result in a north pole, and the current flowing OUT of the coil is assumed to result in a south pole. Notice that at the point in time indicated by each numbered vertical line, the current is flowing in one direction in one of the phases, and in the opposite direction in each of the other two phases.

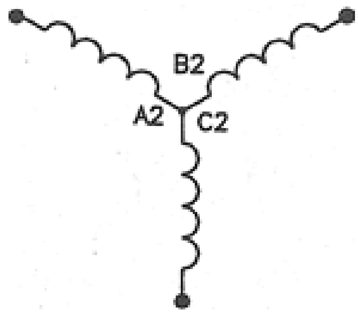
9. At the instant numbered 1, the current is flowing IN in the A-phase and the C phase, and OUT in the B phase, resulting in magnetic poles as shown. Three adjacent north poles are formed and three adjacent south poles are formed, so the axis of the resulting combined magnetic poles is in the direction indicated.

10. At the instant numbered 2, the current is flowing IN in the A-phase and OUT in the B phase and the C phase, resulting in magnetic poles as shown. The polarity of the poles in the C phase has reversed, so the axis of the resulting combined magnetic poles has shifted by 30 degrees in a clockwise direction.

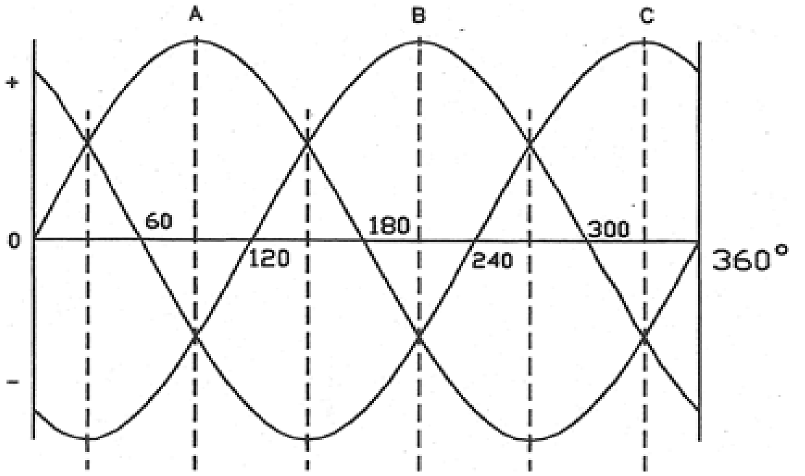
11. If you examine the direction of current at each numbered instant, and the corresponding magnetic poles, you will see that in one complete cycle the axis of the combined magnetic poles has rotated one complete revolution.



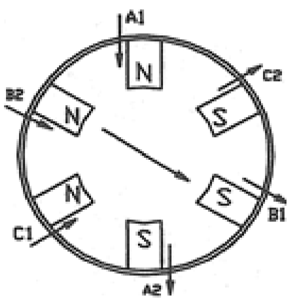
A1 B1



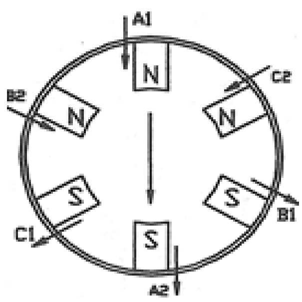
C1



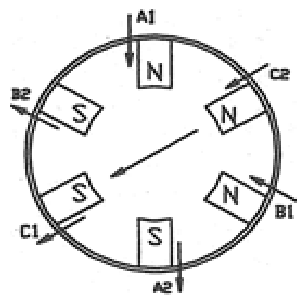
1 2 3 4 5 6



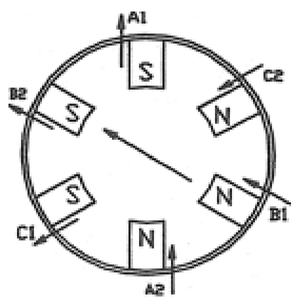
Instant 1



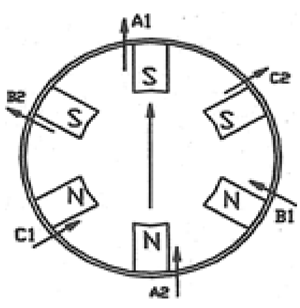
Instant 2



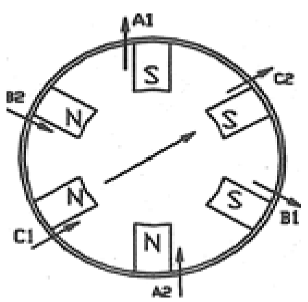
Instant 3



Instant 4



Instant 5



Instant 6

Figure 2 – Three-phase rotating magnetic field
Drawings © North Metropolitan TAFE

12. If the direction of the rotating magnetic field was reversed, the direction of rotation of the rotor would be reversed. The direction of the rotating magnetic field is reversed by reversing .any two of the three incoming supply conductors.

13. In a two-pole motor, the rotating magnetic field completes one revolution for every full cycle of the three-phase supply voltage. Since the supply frequency is 50 Hz (50 cycles per second), the magnetic field rotates 50 x 60 or 3000 times per minute. The speed of the rotating magnetic field is the main factor that determines the speed of a three-phase squirrel cage induction motor, and it is known as the 'synchronous speed'.

14. A similar relationship exists in a three-phase squirrel cage induction motor which has an even number of poles, so the SYNCHRONOUS speed of a motor can be calculated from the equation:

$$N_{syn} = \frac{f \times 120}{P}$$

Where:

N_{sync}	=	Synchronous speed (revolutions per minute – rpm)
f	=	Frequency of supply voltage
120	=	Constant (conversion from seconds to minutes and relationship between magnetic poles and windings)
P	=	The number of poles per phase in the stator

15. Example Calculate the speed of the rotating magnetic field in a three-phase 6 pole squirrel cage induction motor at 50 Hz.

$$N_{syn} = \frac{f \times 120}{P}$$

$$N_{syn} = \frac{50 \times 120}{6}$$

= 1000 r/min

16. Exercise Calculate the speed of the rotating magnetic field in a three-phase 4 pole squirrel cage induction motor at 50 Hz. What would be the synchronous speed of the same motor if it was connected to a 60 Hz supply?

17. The speed you calculate using the equation above is NOT the speed of the rotor; rotor speed is the synchronous speed less 'slip' - slip is explained a little later.

Squirrel Cage Rotor

18. The typical squirrel cage rotor consists of comparatively large bars of conducting material (usual aluminium) cast into the slots in the rotor and joined at each end of the rotor with conducting 'end rings'. No insulation is necessary between the rotor bars and the laminated steel rotor core because the rotor winding has a much lower resistance than the rotor core. An outline of the construction of a typical squirrel cage rotor is shown in Figure 3, but you should bear in mind that rotor bars and end rings can have other shapes and they can be made from other materials (such as copper).

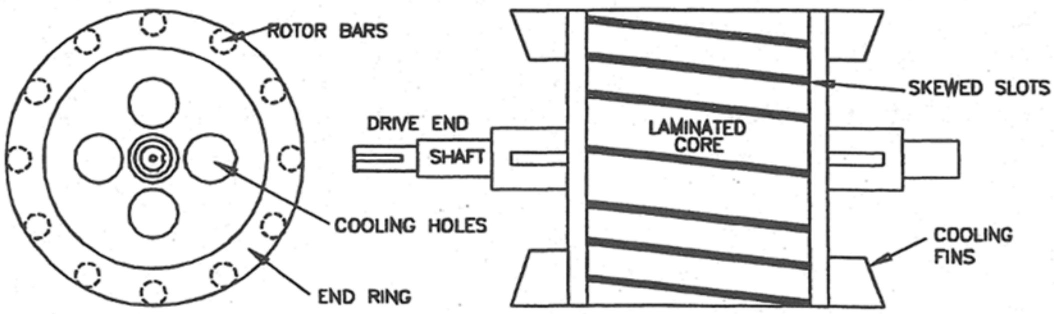


Figure 3 - Typical squirrel cage rotor construction

Drawing © North Metropolitan TAFE

Operation

19. When the rotor is stationary, the alternating current in the stator winding induces a current in the rotor winding in the same way as current is induced in the secondary of a transformer even though there is no electrical connection. The current in the rotor is high because it has a low number of turns compared to the turns on the stator. A significant difference between the operation of a transformer and the current induced in a rotor is that the frequency of the current in the rotor decreases as the rotor speed increases - it is the same as the supply frequency when the rotor is stationary, and almost zero when the motor is running on no load.

20. The magnetic flux caused by the stator current interacts with the magnetic flux caused by the rotor current in such a way that the rotor moves in the direction of the rotating magnetic field. Some rotors have the rotor bars set at an angle to the axis of the rotor; these rotors are said to have 'skewed' slots. Skewed slots result in a smoother torque from the motor and reduced magnetic noise.

21. As the rotor speeds up the frequency of the current in it decreases; if the rotor reached the same speed as the rotating magnetic field there would be no relative movement between the speed of the rotating magnetic field and the rotor winding, therefore there would be no current induced in the rotor - if there was no current in the rotor there would be no magnetic flux to react with the stator flux, so the rotor of a three-phase squirrel cage induction motor can't be turning at synchronous speed (unless it is driven by some other means).

22. If the motor is on no load, the rotor speeds up until there is just enough magnetic interaction to overcome bearing friction and wind friction on the rotor, and the speed stabilises at a value a few revolutions per minute slower than synchronous speed (at about 2995 rev/min in a two-pole machine). At this point the frequency of the current in the rotor is very low, the rotor current is low, and the corresponding stator current is low.

23. As the load is applied to the motor, the magnetic interaction between the rotor flux and the stator flux is no longer sufficient to maintain the rotor speed so the rotor slows down. As the rotor slows down the rotor frequency increases, causing a corresponding increase in rotor current and a corresponding increase in stator current. When the load on the motor reaches a

value that results in the stator current reaching its maximum designed value the motor is said to be running on full load.

24. The difference between synchronous speed and full load speed is known as the 'slip' and is usually expressed as a percentage. A typical value of slip for a three-phase squirrel cage induction motor is between 4 and 6% of synchronous speed on full load. The slip is 100% at the instant the motor is switched on (before the rotor begins to rotate). The value of slip for a particular motor is set by the designer of the motor.

25. Example
Find the no-load and full-load speed of a 415 volt 50 Hz two-pole three-phase squirrel cage induction motor if it has 4% slip on full load.

$$N_{syn} = \frac{f \times 120}{P}$$

$$N_{syn} = \frac{50 \times 120}{2}$$

3000 revolutions per minute (r/min)

Full load speed = Synchronous speed - slip

3000 - (4% of 3000)

3000 - 120

2880 r/min

26. Exercise
Find the no-load and full-load speed of a 415 volt 50 Hz four-pole three-phase squirrel cage induction motor if it has 5% slip on full load.

27. Thus the three factors which govern the full load speed of a three-phase squirrel cage induction motor are:
    a. The number of poles (speed increases as poles decrease).
    b. The frequency of the supply (speed increases as frequency increases).
    c. The amount of load on the motor (speed decreases as load increases).

Torque

28. The starting torque of a standard three-phase squirrel cage induction motor is low compared to some other types of three phase-motor because there is a considerable phase difference between the current in the stator and the current in the rotor (because the rotor circuit is more inductive than the stator circuit).

28. The starting and running characteristics of a particular motor depend on the purpose for which it has been designed, and many variations are possible. The variations are intended to provide the required performance characteristics such as starting torque, full load torque, pull-out torque, starting current, full load running current and overall efficiency. These characteristics are determined by the manufacturer and are rarely adjustable by the electrician, but you need to be aware that one particular three-phase squirrel cage induction motor may have the same power rating as another, but its operating characteristics could be completely different.

29. The manufacturer can vary the performance characteristics of a motor by altering the resistance of the rotor winding, by varying its reactance by altering its physical position in the rotor, by varying the shape of the rotor bars, or by providing more than one rotor winding. Some rotors have skewed rotor bars to provide a smoother torque and reduce magnetic noise.

30. The torque produced by an induction motor is proportional to the square of the applied voltage ($\boldsymbol{T} \propto \boldsymbol{V^2}$). This means that if the applied voltage is reduced to 50% of the designed value, the starting torque is reduced to 50% squared or 25% (50% squared is 50% of 50%, which is 25%),

31. There are two major type variations from the standard three-phase squirrel cage induction motor; the double-cage squirrel cage motor and the wound rotor motor.

The Double Cage Rotor

32. A three-phase double squirrel cage induction motor rotor has two squirrel-cage windings instead of one. One winding is embedded deep in the rotor core and the other is closer to the surface of the rotor core; both windings are connected to the same end rings. The second rotor winding is not usually visible so it is not usually possible to distinguish a single cage rotor from a double cage rotor without reference to the manufacturer's data. Figure 4 shows how double cage rotor bars can be arranged in a rotor.

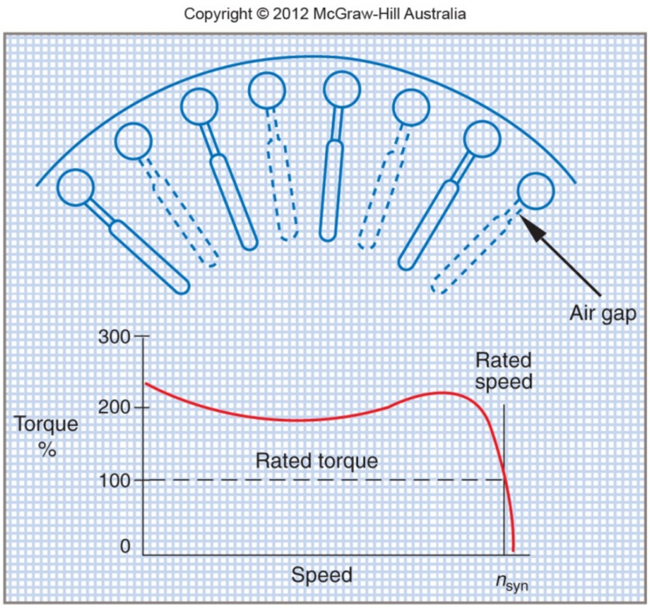


Figure 4 – Double squirrel cage rotor. Used in applications requiring high starting torque

33. The winding which is embedded deeper in the rotor has more inductance than the outer winding, and the outer winding has more resistance. The outer winding provides greater starting torque and the inner winding provides good running torque, but the higher resistance of the outer winding results in a lower overall efficiency for the motor because of the increased copper losses in the rotor.

34. A typical double cage rotor produces about 200-275% of full load torque on starting, with about 5 times full load current.

The Wound Rotor Motor

35. A wound rotor motor (also known as a slip-ring motor) has the same type of stator winding as the three-phase squirrel cage induction motor, but it has a star connected rotor winding which is wound with INSULATED copper wire and connected to three slip-rings on the rotor.
Unlike the squirrel cage rotor, the rotor winding is insulated from the laminated steel rotor core and the resistance of the rotor circuit can be varied by connecting an external star connected a resistance in series with the rotor winding via the slip rings. Figure 5 shows the relationship between the stator winding, the rotor winding and the external rotor resistances.

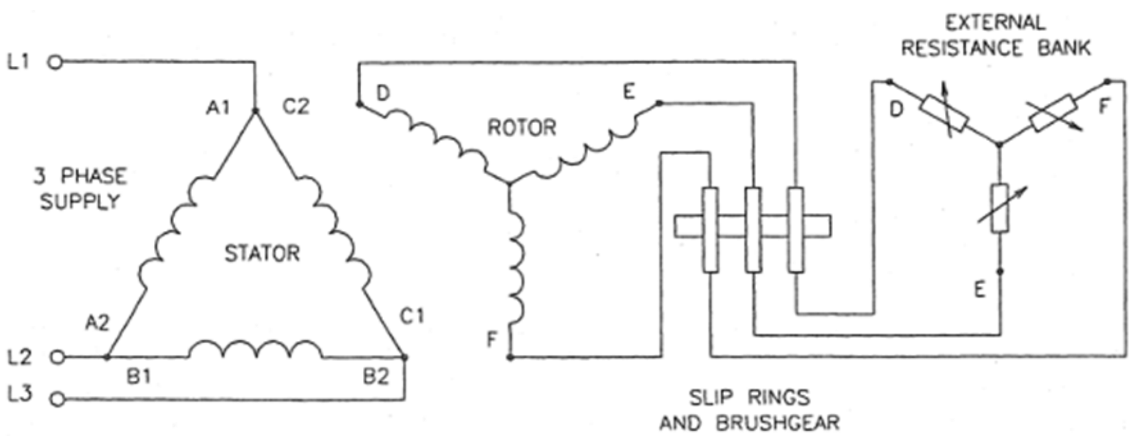


Figure 5 – Stator winding, rotor winding and external rotor resistance bank.
Drawings © North Metropolitan TAFE

36. Being able to control the rotor circuit resistance means that the motor speed and starting current can be controlled by varying the external resistance. Three-phase motor starters or speed controllers which vary the resistance of the rotor circuit are known as secondary resistance starters or drum controllers and they are available in both manual and automatic types.

37. Wound rotor motors usually have a much higher starting torque than standard squirrel cage induction motors but their overall efficiency is lower because of the additional resistance in the rotor circuit.

38. The voltage induced in the rotor of a wound rotor motor is usually much less than the voltage supplied to the stator winding - a typical value of rotor voltage is about 150 volts.

39. Wound rotor motors are usually started with all resistance in the rotor circuit, the resistance is gradually reduced to zero as the motor speeds up. If a wound rotor motor is to be bench tested on no load, the slip rings need to be short-circuited, otherwise, there would be no circuit for the rotor currents and the motor would not run.

Motor Characteristics

40. The operating characteristics of a particular type of induction motor can be shown on a graph known as a characteristic curve or performance curve.
A characteristic curve for a typical general-purpose squirrel cage induction motor is shown in Figure 6.

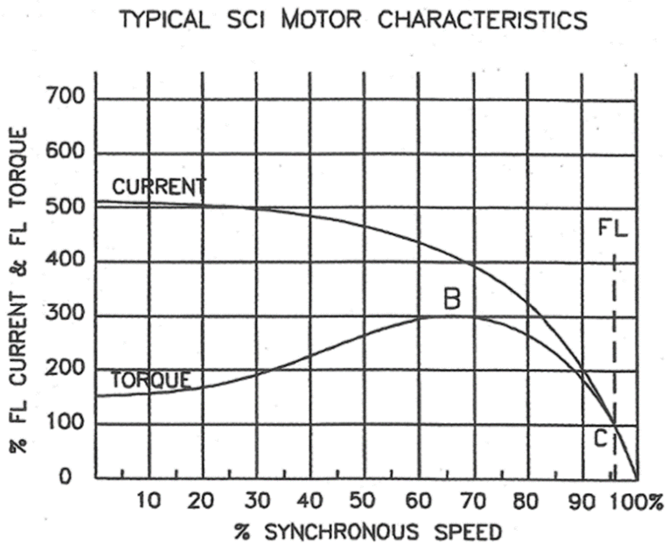


Figure 6 – Typical three-phase induction motor characteristics.

Drawing © North Metropolitan TAFE

41. Figure 6 shows the full load current (FLC) and full load torque (FLT) on the +Y axis, and SYNCHRONOUS speed on the +X axis.

42. You can see from the graph that the initial starting current (A on the current curve) is a little over 500%, and the initial starting torque (A on the torque curve) is about 150% of full load torque.

43. The point marked 'B' on the torque curve is usually known as the 'pull-out torque'.If the motor is running on full load and the load increases still further, the rotor speed falls, the torque (and line current) will increase to the point where the motor is unable to turn the load, so the motor stops. If the circuit protection device does not operate the high current will cause the motor to burn out.

44. The point marked 'C' is the current and torque when the motor is running at its full designed load and with its designed percentage slip. If the load on the motor is reduced, the line current per phase will be reduced, and the slip will decrease (rotor speed will increase). You should note that an induction motor can't operate at 100% of synchronous speed because at that point there is no rotor current so there can be no torque.

45. The shape of the characteristic curves for a particular motor can be varied by the manufacturer, by altering the electrical or mechanical characteristics of the rotor and its winding - as described earlier.

46. Typical characteristics and applications for the most common types of three-phase squirrel cage induction motor are:

General Purpose SCI Motor

Typical characteristics are; about 150% full load torque on starting and about 5 times full load current on starting. See Figure 6 for torque/current characteristics.
Common uses are:

Pedestal grinders
Fans & Air Blowers
Domestic Refrigeration compressors
Motor generator sets
Low inertia machinery

Double-Cage Motors

Characteristics are; about 200-275% full load torque on starting and about 5 times full load current on starting. Common uses are:

Air compressors
Crushers Conveyors
Commercial Refrigeration Compressors
Reciprocating pumps

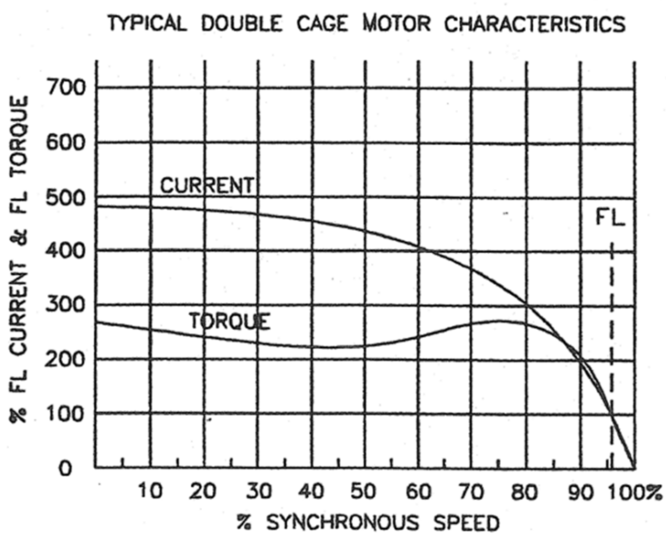
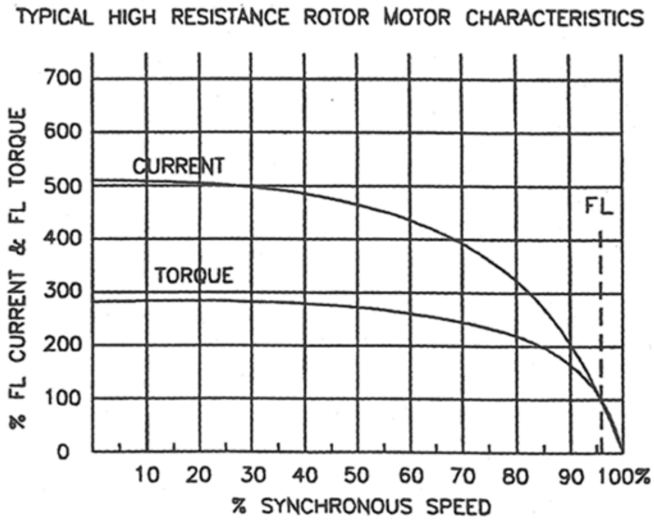


Figure 7.
Drawing © North Metropolitan TAFE

High Resistance Rotor Motors

About 250-275% full load torque on starting and about 5 times full load current on starting.
Uses:

High impact loads Flywheel loads Hoists
Presses
Punches
Shears
Cranes and elevators



Wound Rotor Motors

About 300% full load torque on starting and about 2-3 times full load current on starting when used with external rotor resistance. Typical uses are; Conveyor belts, cranes and lifts.

Drawings © North Metropolitan TAFE

Single Phasing

51. If a three-phase motor loses one phase while it is running on NO load it will continue to run as a two-phase motor with no harmful effect other than an increased line current. If the load on the motor remains less than or equal to a value which results in full load current the motor will continue to run. If the load increases to a value that results in a line current greater than the designed value, the overload mechanism should operate and stop the motor.

52. However, most three-phase motors will not START if there is a loss of supply of one (or two) phases. If the overload mechanism does not operate, the motor will burn out.

Power Factor and Efficiency

53. The power factor of a typical three-phase squirrel cage induction motor is best when the machine is operating on a full load - a typical value is about 0.8 lagging.

54. The efficiency of a typical three-phase squirrel cage induction motor is best when the machine is operating on a full load - a typical value is about 80% or greater. Larger motors can have an efficiency of over 90%

55. Figure 8 shows a summary of the operating parameters of a typical three-phase squirrel cage induction motor.

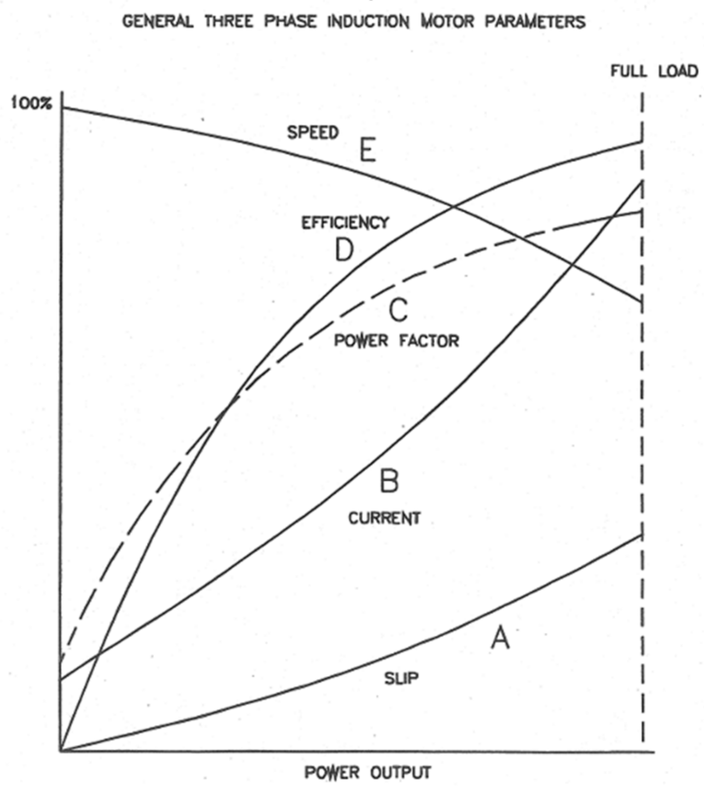


Figure 8 – Typical operating parameters.

Drawing © North Metropolitan TAFE

Note: In Figure 8, the left-hand Y-axis is the synchronous speed of the magnetic field of the motor, the right-hand Y-axis is the full load rotor speed.

56. The output power and full load current (FLC) are usually contained on the nameplate of the motor. If they are not, the power rating of the motor can be estimated using the following equation:

$$P = \sqrt{3} \times V_L \times I_L \times \lambda \times \eta$$

Where:
- P = The output power from the motor in watts
- V_L = The line voltage
- I_L = The line current per phase on full load
- λ = The power factor (Cos θ) is usually about 0.8 lagging.
- η = The efficiency on full load (usually about 80%)

57. If the full load current per phase is not known it can be estimated by transposing the above equation to give:

$$I_L = \frac{P}{\sqrt{3} \times V_L \times \lambda \times \eta}$$

58. A general rule of thumb that can be used to estimate the full load current rating of a 415-volt three-phase squirrel cage induction motor is 'kW X 2'.

59. The main Wiring Rules requirements relating to the installation of motors are contained in Clauses 2.8.2, 4.2.2.4, 4.3.1, 4.13, & 7.2.9.

60. The WA Electrical Requirements specify local requirements for electrical equipment with inrush current (such as motors) in Section 3.5.

Minimum Energy Performance Standards

61. Minimum Energy Performance Standards (MEPS) specify the minimum level of energy performance that appliances (including motors) must meet or exceed before they can be offered for sale or used for commercial purposes.
MEPS are an effective way to increase the energy efficiency of products. By specifying a minimum energy performance level they prevent inefficient products from entering the marketplace and help to increase average production efficiency over time. For consumers, this means that products available in the market use less energy and have lower running costs over the life of the product. Using energy-efficient products also reduces greenhouse gas emissions and our impact on the environment.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-6	Version 4 2021

Three-phase Motor Operation

I. What is the rotor speed of a 50 Hz three-phase four-pole squirrel cage induction motor if it is running with 4% slip?

2. Will a three-phase squirrel cage induction motor start unaided on two phases?

3. What 'rule of thumb' can be used to ESTIMATE the approximate full load current in a three-phase415 volt induction motor?

4. What is the name given to the electromagnetic principle on which a three-phase induction motor operates?

5. How can the direction of rotation of a three-phase induction motor be reversed?

6. What is the most common material used to form the conductors in the rotor of a typical 5 kW squirrel cage induction motor?

7. Why are the rotor conductors in some squirrel cage induction motors 'skewed'?

8. What essential electrical safety tests must be carried out on a three-phase motor before it is connected to the mains?

9. Under what conditions would it be possible for the speed of a three-phase50 Hz squirrel cage induction motor to exceed 3000 +/min?

10. What is the advantage of a double squirrel cage motor compared to a single cage motor?

11. The nameplate of a three-phase induction motor gives the speed as 960 revolutions per minute. What is the 'synchronous speed' of the motor?

12. Why is it physically impossible for the speed of an induction motor to equal its synchronous speed?

13. A three-phase motor nameplate gives the current rating of 18 amps. When would the line current be 18 amps?

14. What is meant by the term 'synchronous speed' when applied to induction motors?

15. A particular three-phase motor has 'f = 60Hz' marked on the nameplate. Would it be safe to operate the motor on full load at 50 Hz?

16. A 4 kW 415-volt squirrel cage induction motor is designed to be connected in the star has a full load current rating of 8 amps. Would it be safe to connect the motor to a 415 volt supply in DELTA?

17. Write down the equation that can be used to determine the speed of the rotating magnetic field in a three-phase stator?

18. The speed shown on the nameplate of a three-phase motor is 1420 r/min. When would the speed of the motor be 1420 r/min?

19. What is the frequency of the ROTOR current at the instant a three-phase induction motor is switched on?

20. What are the three main factors governing the operating speed of an induction motor?

21. The nameplate of a three-phase induction motor gives the speed as 1400 r/min. What would be the approximate speed if the motor was bench tested on NO LOAD at its full rated voltage?

22. A three-phase induction motor runs at just under 3000 r/min on no-load when connected in STAR. What would be the approximate no-load speed if the same motor was connected in DELTA?

23. A three-phase induction motor runs at just under 1500 r/min on no load. What would be the approximate no-load speed if the direction of rotation was reversed?

24. Refer to Figure 1. (on the following page) Which of the motor characteristic curves represents a typical standard three-phase induction motor?

25. Refer to Figure 1. (on the following page) Which of the motor characteristic curves represents a typical three-phase double cage induction motor?

26. Refer to Figure 1. (on the following page) Which of the motor characteristic curves represents a typical three-phase high resistance rotor induction motor?

27. Refer to Figure 1. (on the following page) Which of the motor characteristic curves represents a typical three-phase wound rotor induction motor?

28. What effect does it have on the operation of a standard three-phase wound rotor motor if any two of the ROTOR connections are reversed?

29. How many slip rings are required on the shaft of a three-phase wound rotor motor?

30. If a wound rotor motor is running at full speed on full load, would the resistance of the rotor circuit be maximum or minimum?

31. How should a 2 kW wound rotor motor be connected to bench test it for operation on no load?

32. What is a typically rated rotor voltage in a wound rotor motor?

33. When is the rotor frequency greatest in a three-phase wound rotor motor which is connected to 415 volts AC?

34. What is the minimum number of terminals required on the terminal block of a wound rotor motor?

35. To which winding in a three-phase wound rotor motor must the three-phase supply be connected?

36. Will a three-phase wound rotor motor start if the rotor circuit is open-circuited?

37. How can the speed of a three-phase wound rotor motor be varied?

ANSWERS PAGE 236

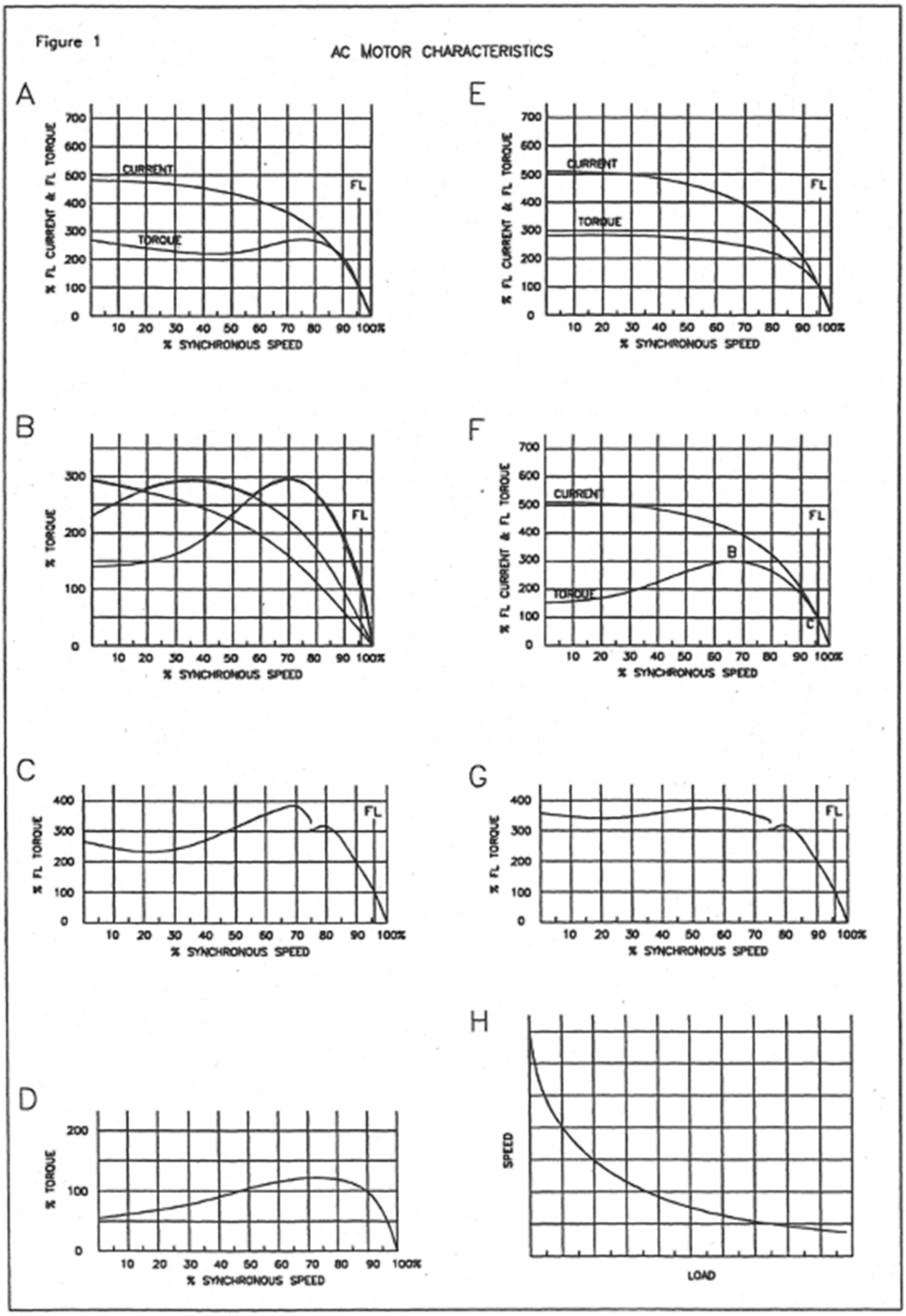


Figure 1 – Motor Characteristics

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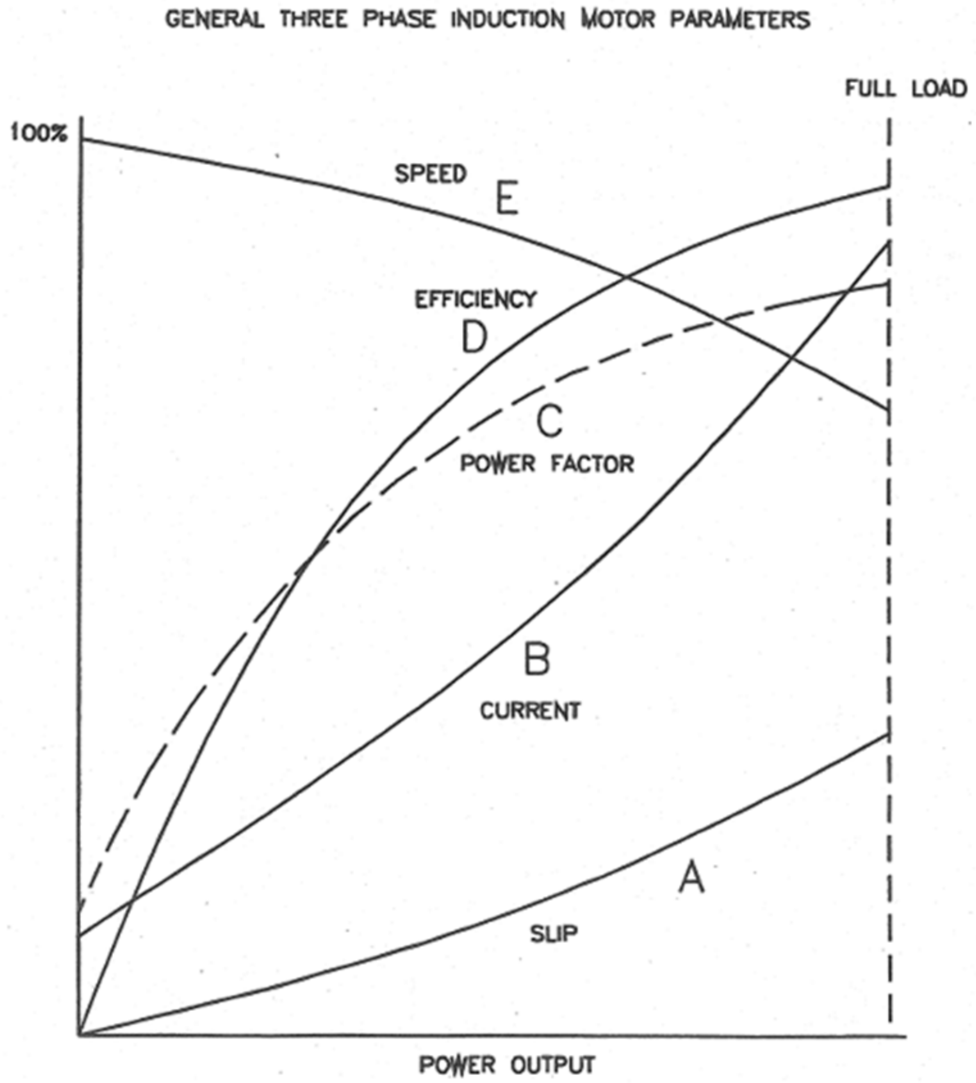

Figure 2. – Information for Q. 33

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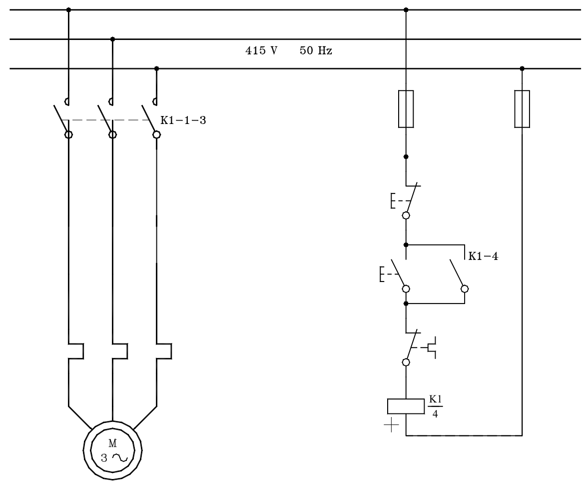
3.7 - Three-phase DOL Motor Starters

Direct On Line Starting (DOL Starting)

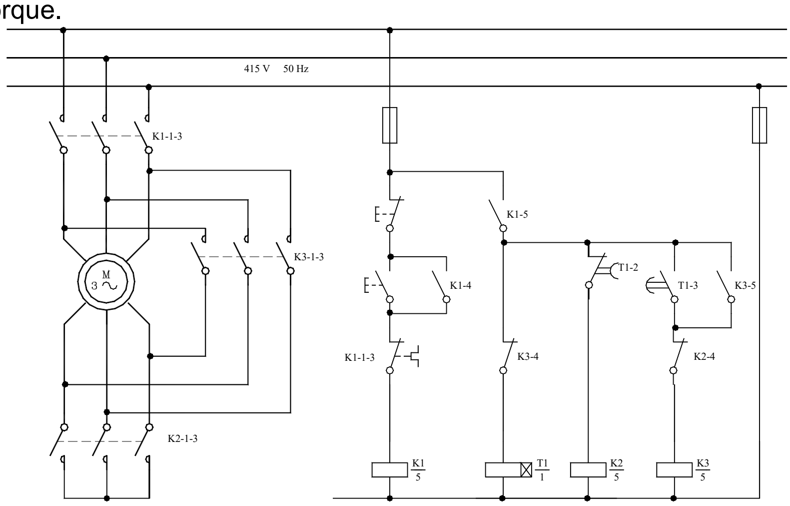
1. Many squirrel cage motors are started 'direct on-line (DOL), using a three-phase magnetic contactor. These have the advantage of simplicity, high starting torque and cheapness although the starting currents are high, (typically 4 to 6 times full load current for 1-2 seconds).



2. Section 3.5 (Loads Affecting Other Customers) of the WA Electrical Requirements specifies the maximum inrush current permissible so other consumers are not affected. For these limits to be exceeded written approval from the network operator must be obtained.

Star-Delta Starters

3. DOL motor starters produce the maximum amount of torque from a given motor, but they also draw the most current on starting. Most three-phase motors over about 3 kW are started using a starter which limits the starting current to a lower value than DOL, but this is at the expense of starting torque.



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4. The star-delta starter is commonly used, but it requires a three-phase motor which is designed to run continuously in DELTA, and in which the leads from each phase in the motor are brought out to a six terminal block.

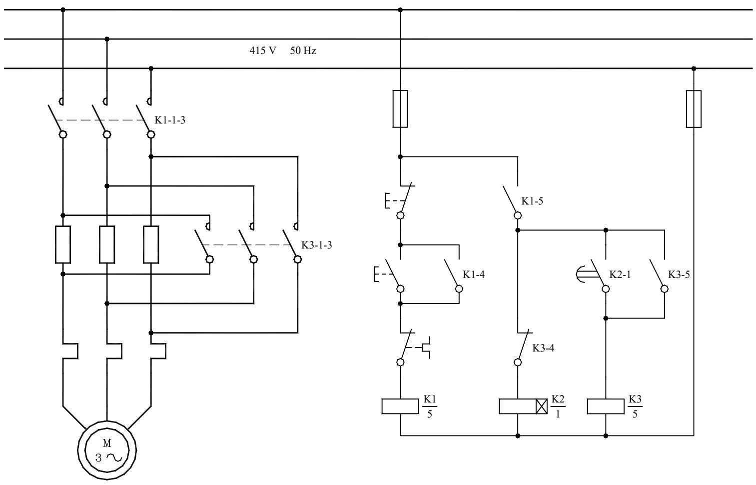
5. When a motor is started on a reduced voltage, the starting torque must be lower than it would be if started DOL - the starting torque is proportional to the SQUARE of the voltage applied to the motor. Thus if the voltage to a motor was reduced to 50% of its full designed value, the starting torque would be reduced to 50% squared which is 25% (50% of 50%). So starting torque and starting current are reduced to 1/3 of their DOL values when the motor is started in star.

$$T \propto V^2$$

6. After a period of acceleration, a suitable switching process is used to disconnect the motor from the supply, remove the star connection and reconnect the windings in the delta. Star-delta starters are available in either manual or automatic types. Manually operated types are usually interlocked (mechanically) so that the starter cannot be put directly into the delta.

Primary Resistance Starters

7. A primary resistance starter has a switching arrangement whereby the motor is first connected to the line with a resistor in series, and then after it has accelerated it is switched directly online. The value of the starting current is limited by the value of the series resistor in each phase.



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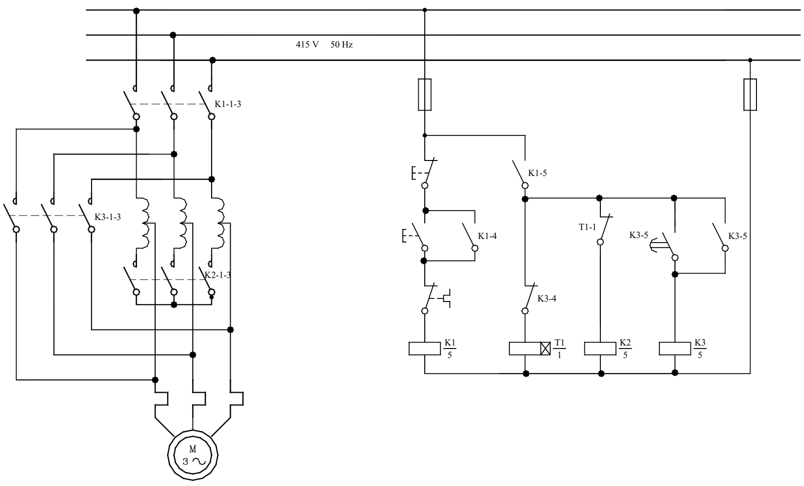
8. The line resistors can be cut out in steps to provide controlled acceleration if a suitable control circuit is used.

Two-Step Primary Resistance Starter

9. The circuit for a two-step primary resistance starter is very similar to that of the standard primary resistance starter but with the two-step starter having an additional bank of series resistors in the power circuit and an additional timing stage in the control circuit. Other steps could be added to provide a smoother acceleration if required.

Autotransformer Starters

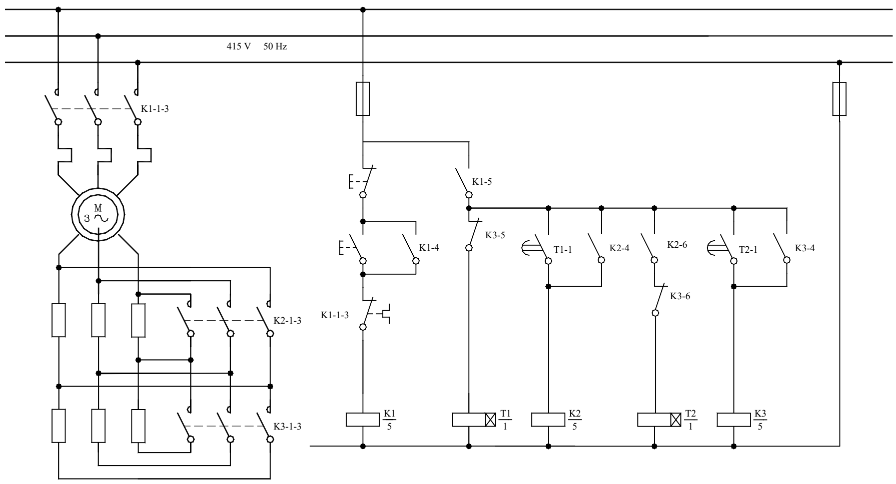
10. A three-phase autotransformer starter reduces the line current to a squirrel cage induction motor by reducing the line voltage to the motor during starting. The line voltage is reduced using a three-phase autotransformer which has tapping's to provide various set percentages of the line voltage for different load conditions.



11. Two types of autotransformer are in common use - a three-coil transformer and a two coil transformer. The three coil autotransformer is star connected and the output is taken from one of the tapping's provided on each coil (the same tapping must be used for each coil). The two coil autotransformer is connected 'open delta', which is a method of obtaining a three-phase output from a transformer using two instead of the usual three.

Secondary Resistance Starters

12. A three-phase secondary resistance starter is a current limiting starter that reduces starting current by connecting resistors in the ROTOR circuit during starting. Secondary resistance starters can only be used with three-phase wound rotor (slip ring) motors.



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13. There are two main types of secondary resistance starters - manual and automatic. Unlike other types of manually operated three-phase motor starters, secondary resistance starters are still relatively widely used they are often known as 'drum controllers' because they are used to control the speed and direction of the motor.

$$Speed = \frac{120 \times f}{Poles}$$

14. None of the above starters affects the operating speed of the motor. Induction motors operate at the synchronous speed determined by the above equation. The speed of the rotating magnetic flux is determined by the number of poles and the frequency of the supply. The actual full load speed is determined by the synchronous speed minus slip. Slip is approximately 4% of sync speed.

15. For example, a 4-pole motor that is connected directly to 50 Hz would have a synchronous speed of 1500 RPM:

$$Speed = \frac{120 \times f}{Poles}$$

$$Speed = \frac{120 \times 50}{4}$$

$$Speed = 1500\ RPM$$

Therefore full load speed is 1500 – 60 (4% of sync speed) approximately 1440 RPM.

Three-phase Electronic Starters (Information only)

16. An electronic starter is a solid-state device that reduces the voltage to a three-phase motor during starting, thus limiting the starting current. They are often called 'soft starters' because they can be set to start the motor with virtually no mechanical shock to the system.

17. Typical electronic motor starters do not incorporate magnetic contactors - the reduction in voltage is achieved using appropriate electronic switching circuitry involving components such as diodes, silicon controlled rectifiers (SCRs) and TRIACs.

18. The advantages of using electronic starters compared to other types of motor starters include:

a. Small physical size.
b. Smooth, stepless voltage control.
c. Contactless operation.
d. Reduced maintenance requirements.
e. Control of starting modes.
f. Possible control of deceleration as well as acceleration.
g. Reduced internal power losses compared to other starters.

19. Electronic starters cannot provide a starting torque higher than that which would be developed by the motor if it was started DOL, but they can provide much greater control of the torque and current. The relationship between starting voltage and starting torque (torque is proportional to the square of the voltage) applies to electronic starters as it applies to other starters.

Variable Frequency Drive

20. A Variable Frequency Drive (sometimes abbreviated VFD) is a system for controlling the rotational speed of an AC motor by controlling the frequency of the electrical power supplied to the motor. Variable frequency drives are also known as adjustable frequency drives (AFD), variable speed drives (VSD), AC drives or inverter drives.

21. Variable frequency drives operate under the principle that the synchronous speed of an AC motor is determined by the frequency of the AC supply and the number of poles in the stator winding, according to the relationship:

$$Speed = \frac{120 \times f}{Poles}$$

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-7	Version 4 2021

Three-phase DOL Motor Starters

1. What is the only type of DOL starter that can be used to start or stop a motor from more than one remote location?

2. Can a three-phase415 volt motor be started from a starter that has a 24-volt control circuit?

3. Where should overload contacts be connected in a magnetic motor starter?

4. Can a DOL starter be used to start a SIX terminal three-phase motor?

5. A DOL motor starter is being used to control a motor that has a full load current rating of 50 amps, a starting current of 250 amps and a control circuit current of 20 milliamps. To what value should the overloads be set?

6. Name the three major electrical components which make up a typical DOL motor starter.

7. What is the main disadvantage of starting a three-phase SCI motor DOL?

8. What is the main advantage of starting a three-phase SCI motor DOL?

9. What section of the WA Electrical Requirements provides the regulations of limiting inrush current of three-phase motors?

Star-Delta Starters

1. What are the two general types of three-phase star-delta starters?

2. What are the typical Australian markings for the MOTOR terminals on a star-delta starter?

3. What are the typical Australian markings for the incoming LINE terminals on a star-delta starter?

4. What are the typical markings for the incoming LINE terminals on a star-delta starter of European origin?

5. What type of motor can be started using a star-delta starter?

6. What is meant by the term 'single phasing' of a three-phase delta connected motor?

7. A 415-volt three-phase motor is connected to an automatic star-delta starter. What voltage would be measured between motor terminals A1 and A2 when the starter is in the START condition?

8. What is the main DISADVANTAGE of using a current limiting starter instead of a DOL starter?

9. What is the main reason for using a star-delta starter (other than to start the motor)?

10. How many cables are required between a star-delta starter and its associated motor (not including the earth)?

11. An automatic star-delta starter is connected to a suitable motor for the first time. The motor runs correctly in star, but it stops when the starter switches to the delta. What is the most likely fault?

Primary Resistance Starters

1. List the major components which would be found in a self-contained three-phase automatic primary resistance starter.
2. An existing three-phase star-delta starter is to be replaced with an appropriate primary resistance starter. How should the motor be connected?
3. What is the minimum number of motor terminals required for a three-phase motor to be connected to a primary resistance starter (not including the earth)? How would they be marked?
4. How many incoming LINE terminals would be provided on a primary resistance or autotransformer starter? How would they usually be marked?
5. What type of three-phase squirrel cage induction motor starter would be most appropriate if a starting current of about 25% of the DOL value was required?
6. What is one advantage of a primary resistance starter over a standard star-delta starter for starting a 60 kW three-phase motor?
7. How many large power resistors would be expected in a three-phase TWO-STAGE primary resistance starter?
8. Why is it that primary resistance starters do not produce a large current surge when they switch from start to run?
9. Would a primary resistance starter be suitable for use to start a piston-type air compressor?

Autotransformer Starters

1. How is the motor starting current limited with a three-phase autotransformer starter?
2. List the major components which would be found in a self-contained three-phase automatic autotransformer starter.
3. What is the minimum number of motor terminals required for a three-phase motor to be connected to an autotransformer starter (not including the earth)? How would they be marked?
4. How many incoming LINE terminals would be provided on an autotransformer starter? How would they usually be marked?
5. What type of current limiting starter would be most appropriate for starting a squirrel cage induction motor under a heavy load?
6. What is the minimum number of coils which could be expected on the transformer of a three-phase autotransformer starter?
7. What are three of the common tappings on an autotransformer starter?

<u>ANSWERS PAGE 238</u>

Secondary Resistance Starters

1. All secondary resistance starters have at least one electrical interlock. What is the purpose of the interlock?

2. What are the customary Australian terminal markings for the connections from the stator winding of a three-phase wound rotor motor?

3. How should the direction of rotation of a three-phase wound rotor motor be reversed?

4. What is the MINIMUM number of cables required between a two-stage secondary resistance starter and a three-phase wound rotor motor (including earth if required)?

5. What effect does it have on the operation of a standard three-phase wound rotor motor if any two of the ROTOR connections are reversed?

6. How many slip rings are required on the shaft of a three-phase wound rotor motor?

7. If a wound rotor motor is running at full speed on full load, would the resistance of the rotor circuit be maximum or minimum?

8. What are two advantages of a three wound rotor motor compared to a standard squirrel cage motor?

9. What are the customary Australian terminal markings for the connections from the ROTOR winding of a three-phase wound rotor motor?

10. What is the minimum number of terminals required on the terminal block of a wound rotor motor?

11. What is the minimum number of brushes required in a three-phase wound rotor motor?

North Metropolitan TAFE	Electrical Fitting Revision Program (EFRP)	Summary	Version 4.1
Electrical Trades	EFRP Section 3	3-8	2021

3.8 - Lamps

1. Many different types of lamps are made that fall into two main categories - filament and discharge. Filament lamps are generally cheaper, they have good colour rendering properties, but their efficacy is low, whereas the basic discharge lamps have the opposite characteristics. In most lighting applications a compromise is made between the quantity and quality of light required.

2. The main types of lamps in common use are:

   a. incandescent (filament lamp)
   b. tungsten halogen (filament lamp)
   c. fluorescent (discharge lamp)
   d. mercury vapour (discharge lamp)
   e. sodium vapour (discharge lamp)
   f. neon (discharge lamp)

3. There are variations of each basic type, each with its particular application. The different types can be compared based on:

   a. efficacy - lumen output/wattage input
   b. life average
   c. colour rendering
   d. cost - initial and running cost
   e. physical size and shape
   f. auxiliary equipment required
   g. reliability in service
   h. dust or fog penetrating ability
   i. ambient operating temperature range
   j. special handling precautions

Incandescent Lamps

4. Incandescent lamps produce light as a result of the heating effect of an electric current flowing through a filament wire. When the temperature of the wire is raised sufficiently, visible light is emitted. A predominantly 'red' light is produced by incandescent lamps.

5. In normal air, the filament would evaporate due to its high operating temperature. Enclosing the filament in an evacuated glass envelope limits the evaporation to an acceptable level.

Base Configurations

6. There are numerous base configurations available but those most applicable to mains operated incandescent lamps are shown below - these are:

   a. Bayonet cap (BC) available from 15 W to 200 W.
   b. Edison screw (ES) available from 15 W to 200 W.
   c. Goliath screw' (GES) available from 300 W to 1500 W.

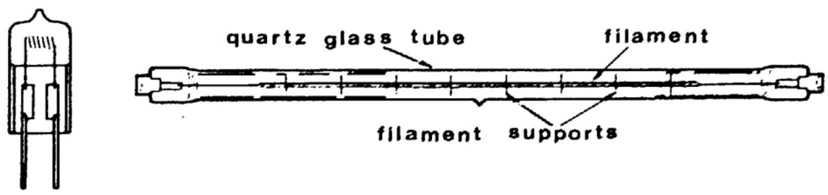
7. Other types of lamp bases are listed below.

Description	Abbreviation
small bayonet cap	SBC
bayonet cap	BC
bayonet cap - 3 pin	3 pin BC
candelabra screw	CAND
small Edison screw	SES
Edison screw	SES
goliath Edison screw	GES

<u>Tungsten Halogen Lamps</u>

8. The tungsten-halogen lamp has distinct performance and design merits over the conventional incandescent lamp. These include its near 100% lumen output throughout life, its increased life (2000 hours) and efficacy (22 lm/W), with a filament of higher luminance, and its strong compact bulb.

9. In conventional tungsten filament lamps, the tungsten which evaporates from the filament is deposited on the bulb wall causing darkening of the glass wall and subsequent loss in efficiency. Additionally, the filament becomes thinner as this migration takes place and eventually it fails. The quartz glass tube in tungsten halogen lamps must not be touched with bare fingers.



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Luminous Discharge Lamps

<u>Principle of Operation</u>

10. When a suitable high voltage is applied to electrodes in the ends of a glass tube containing an inert gas, an electrical discharge or arc occurs between the electrodes. The discharge radiates energy in the form of visible and invisible light. When visible light is emitted it is known as a luminous discharge.

11. The luminous efficacy of a gas discharge lamp is much greater than that of an incandescent lamp because a much larger percentage of the energy produces visible light (directly or indirectly). In an incandescent lamp, much power is used up in producing invisible radiation and heat.

12. Some discharge lamps produce light directly, while others produce light by converting invisible light to visible light using fluorescent powders or phosphors on the inside of the glass tube. The colour of the discharge depends on:

    a. Type of gas.
    b. The pressure of the gas.
    c. The fluorescent powder used.

Limitation of Current

13. As soon as the discharge in the tube has started, one electron striking an atom will release further electrons creating an avalanche effect. Due to this avalanche of free electrons the voltage required to maintain the discharge decreases, but the current increases (increase in electron flow). Unless there is some immediate reduction in current flow the tube would be permanently damaged.

Current Limiting Devices

14. The current flow can be limited by one of three methods:

    a. Resistor - normally used in D.C. circuits only.
    b. Leakage Transformer - used in A.C. circuits: it will also provide the high voltage required in some circuits.
    c. Ballast or Choke - used in A.C. circuits: it can also produce an inductive kick (high voltage peak) to initiate conduction in certain tubes.

Types of Discharge Lighting

15. Discharge lighting includes:

    a. Neon lighting (Cold Cathode)

In this type, light is produced directly by the radiation from the discharge. The colour of the light depends on the type of gas used and the colour of the glass tube. Neon gas gives a red light and argon gives a blue light. A neon lighting system requires a continuous high voltage (5-10 kV) to strike and maintain the discharge. A neon lamp circuit usually includes a leakage transformer to limit the operating current.

The efficacy of neon lighting is 5-10 times greater than incandescent lighting because a much larger percentage of the energy input is converted to light. The running cost of a neon installation is very small and the life of a neon tube is about 3000 running hours compared to 1000 for an incandescent unit.

Neon lighting is very seldom used for general lighting due to its colour output, but because the neon tube can be started and stopped almost instantaneously it is frequently used for rapidly flashing signs, stroboscopes or engine timing lights.

    b. Sodium Vapour Lamps – Low Pressure and High Pressure

There are several different types of sodium vapour lamps, the main difference being the pressure at which the luminous discharge occurs.

The low-pressure operation is as follows. The high voltage from the leakage transformer causes a luminous discharge between the two electrodes, thus ionising the neon gas in the glass U tube. The heat of the discharge gradually vaporises the metallic sodium and the light output improves as it does so. The lamp takes about 7 to 10 minutes to reach full brilliance. When the discharge is started, the current in the circuit is limited by the leakage transformer. The vacuum in the lamp prevents the escape of heat and thus improves the efficacy of the lamp. The light given off is a brilliant yellow, almost all the visible energy being concentrated at 589 nanometers.

If this lamp is switched off, it will often not restart until the sodium vapour has solidified, which could take about 15 minutes. The light output is relatively constant with a 10% rise or fall in supply voltage, The luminous efficacy is around 150-200 lumens per watt and the rated life is 6000 hours.

Since the light output is monochromatic, it can penetrate fog and dusty atmospheres better than white light. Sodium vapour lamps are used where plenty of light is required, but where the colour rendering is not important such as large parking areas, security lighting in factories, lights over crosswalks, storage areas, aerodrome boundaries and some street lighting.

High-Pressure Sodium Lamps. Modern developments in the manufacturing of the arc tube have enabled Sodium lamps to operate at a higher pressure and temperature, resulting in a more acceptable colour distribution in light output (whiter light). The arc tube is made of sintered aluminium oxide to withstand the intense chemical activity of sodium vapour at high temperatures and pressure.

The high-pressure operation is as follows. The lamp is started by a high voltage pulse supplied by an external solid-state ignitor, which ceases to function when the arc is struck. A conventional ballast is used to limit the running current. The lamp takes 4 to 5 minutes to run up to full brightness, but will normally restrike within 1 minute of extinction and rapidly regain full light output. This is a considerable improvement on the restriking times of low-pressure lamps. Low wattage lamps (50-70 W) are available with an internal ignition device.

The luminous efficacy (within the range of 100-150 lumens per watt) is lower than the low-pressure units due to the disappearance of the monochromatic yellow light during the lamps run-up time. When the lamp is at full brilliance a much broader distribution across the visible spectrum is obtained. Their life rating is 8000-12 000 hours.

The improved colour rendering and very good efficacy of these lamps make them ideal for situations where low running costs and low colour discrimination are required. Some typical examples are high mounted floodlights in industry, freeways, highways and streets, car parks and some sports grounds.

c. Mercury Vapour Lamps – Low Pressure (Fluorescent) and High Pressure

The basic mercury discharge lamp emits a very bluish colour and tends to distort subject colours. These lamps are acceptable where colour rendering is not important due to their efficiency, reliable starting and long life (12 000-24 000 hours).

When the lamp is switched on a luminous discharge occurs in the neon or argon gas between the striking horn and the cold cathode. The heat developed vaporises the mercury, increasing the pressure until the main discharge is initiated between the main electrodes. When the main discharge is in operation, its lower resistance automatically cuts out the auxiliary electrode. This lamp takes 5 or 6 minutes to reach full brilliance. It will not relight immediately if switched off, because of the high vapour pressure in the lamp. This lamp does not emit much red light so the colour rendering is poor.

d. Self-Ballasting Mercury Tungsten lamps

As the name suggests this type of lamp does not require external ballast but relies upon a tungsten filament in series with the arc tube to limit the discharge current. The filament not only acts as a current limiting device, but it also provides light and colour correction to the output of the mercury discharge.

Lamps are available with ES or BC cap and can be used as a direct replacement for normal incandescent lamps giving higher light output and six times the life.

In an installation where discharge lamps are used as the primary source of light, there is always the danger, in the event of a momentary power failure, of the lamps being extinguished for a few minutes due to the delay in their restrike time. It is recommended that incandescent lamps should be dispersed between the discharge lamps to provide sufficient light during this time. The filament in a self-ballasting lamp will cover this emergency.

e. Metal Halide Lamps

These lamps operate on the same principle as all gas discharge lamps and are high-pressure mercury vapour lamps with metal halide additives (sodium, thallium and indium iodides) to the quartz arc tube. The special additives in the arc have almost doubled the light output and improved the light distribution throughout the visible spectrum, giving the best colour rendition of all the discharge lamps except some fluorescent lamps.

Metal halide lamps have an efficacy of 70-100 lumens per watt with a run-up time of 10-15 minutes and a restriking time of 2-7 minutes. A reduction of the starting and restrike times is available in special types. Their life rating is from 5000 hours to 12 000 hours, which varies according to type and mounting position.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-8	Version 4 2021

Lamps

1. What term is usually used to describe the 'size' of an illuminating lamp?
2. What is the approximate ratio between the 'cold' resistance and the 'hot' resistance of an incandescent illuminating lamp?
3. What common type of lamp holder is always made from porcelain?
4. What type of incandescent lamp has a glass envelope which must not be touched with bare fingers?
5. What fault is indicated if a failed incandescent lamp has the inside of its glass envelope filled with a white powder?
6. What two conditions could be indicated if a failed incandescent lamp has a thin black film on the inside of the glass envelope?
7. What is the special requirement for connecting Edison Screw lamp holders according to the Wiring Rules?
8. What is the major disadvantage of an incandescent lamp?
9. What item of control equipment is required with most illuminating lamps which operate on the 'gas discharge' principle?
10. What potentially dangerous situation can arise if a single gas discharge lamp is used over a rotating machine?
11. What is the main factor which determines the colour at which a 'neon' lamp operates?
12. What type of control equipment is usually installed with a neon illuminating lamp?
13. What is the characteristic colour given off by a low-pressure sodium vapour lamp when it is operating at full brilliance?
14. What additional item of control equipment must be connected in discharge lighting circuits which incorporate a ballast or leakage transformer?
15. What precaution must be taken when disposing of sodium vapour lamps?
16. What is the characteristic colour given off by a mercury vapour lamp when it is operating at full brilliance?
17. Why is it dangerous to operate a mercury vapour lamp if the outer glass envelope is broken?
18. What type of mercury vapour lamp can be installed without any additional control equipment?
19. What three items of control equipment are usually required with high-pressure mercury vapour or metal halide lamps?
20. What is the special characteristic of a 'blended' mercury vapour lamp?

ANSWERS PAGE 240

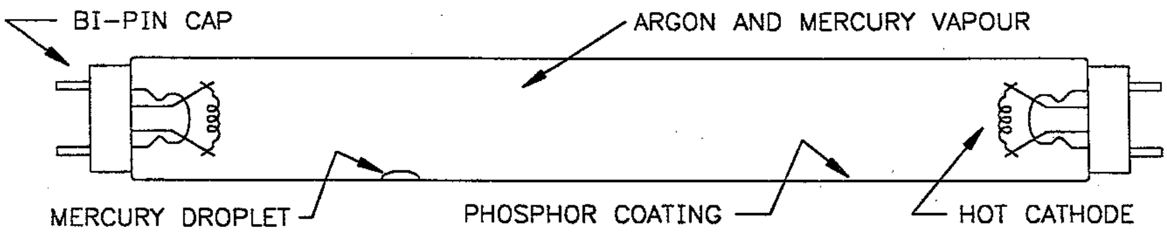
North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Summary 3-9	Version 4.1 2021

3.9 - Fluorescent Lighting

Fluorescent Lamps

1. The fluorescent lamp uses an electric discharge in mercury vapour at very low pressure to produce ultraviolet radiation. This radiation is converted to visible light by a fluorescent powder phosphor coating on the lamp wall.

2. A fluorescent lamp consists of a straight or bent glass tube coated on the inside with a phosphor powder and provided with caps at each end - See Figure 1. The pins maintain the contact between the lamp holder and the cathodes inside the tube.



Drawing © North Metropolitan TAFE

Figure 1 - General construction of a standard fluorescent tube.

3. The inert gas argon is added to the mercury vapour to assist starting since the vapour pressure of the mercury is very low.

4. The types of phosphors used to determine the colour appearance, and to some extent, the efficacy of a lamp and may be divided into two groups:

   a. One which gives the highest attainable efficacy.
   b. Where efficacy is sacrificed to give better colour rendering.

Auxiliary Control Equipment

5. The conventional fluorescent lamp on A.C. requires the following control equipment.

   a. Ballast or choke A fluorescent tube ballast is an inductive coil wound on a laminated core, encapsulated in pitch or polyester to reduce hum, and enclosed in a metal box.· Their main purpose is to limit the discharge current once the tube has struck.
   b. Starter Switch The function of the starter switch is to accurately time the pre-heating of the cathodes of the lamp until the proper starting conditions are reached with a minimum loss of electron emissive materials from the filament.

Typical Fluorescent Lamp Circuit

6. A typical circuit for a single 36-watt fluorescent lamp is shown in Figure 2.

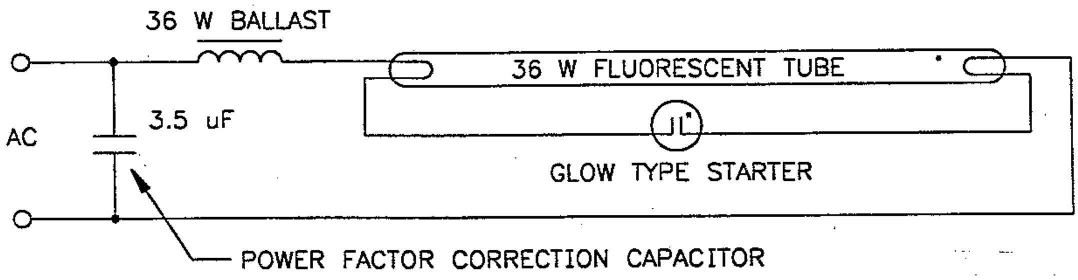
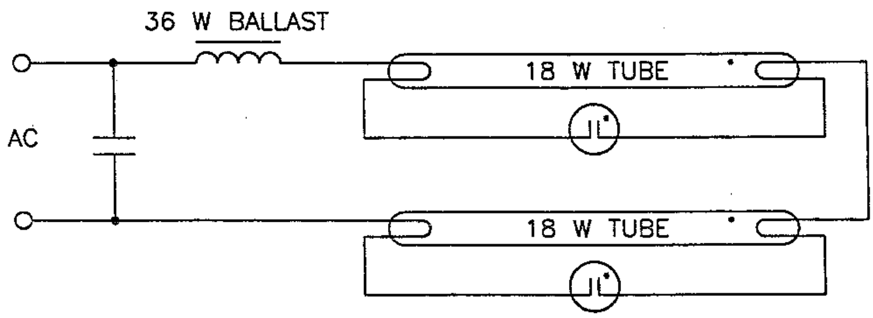


Figure 2 - A typical 36-watt fluorescent lamp circuit.

Twin 18 W Switch Start



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North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-9	Version 4 2021

Fluorescent Lighting

1. What are the standard nominal lengths of each of the following tubular fluorescent lamps: 18/20 watt, 36/40 watt and 65/80 watts?

2. What type of device is used to limit the operating line current in a 240-volt fluorescent lamp circuit?

3. What effect does it have on the operation of a 240-volt 36-watt fluorescent lamp if the power factor correction capacitor has been disconnected?

4. What resistance would be measured between the contacts of a glow-type fluorescent starter when it is not connected in a circuit?

5. The ends of a fluorescent lamp glow brightly when it is switched on but the lamp does not strike. What is the most likely cause?

6. Draw the circuit of a typical twin 18 (20) watt luminaire supplied from a single 36 (40) watt ballast.

7. What are the two functions of the ballast in a 36-watt fluorescent unit?

8. Why are fluorescent lamps unsuitable for installations in which they would be frequently switched on and off?

9. Concerning conventional fluorescent lamp circuits, what item of auxiliary control equipment, other than a ballast or starter switch, is needed to satisfy Supply Authority requirements?

10. Which type of fluorescent circuit is suitable for use over rotating machinery?

<u>ANSWERS PAGE 243</u>

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Summary 3-10	Version 4.1 2021

3.10 - Electrical Testing Devices

1. There are three main reasons why tests are made on electrical circuits and equipment.

   a. To diagnose the cause of failure of a circuit or piece of equipment and locate if possible the exact position of breakdown.

   b. To ensure that a new installation is free from faults and complies with the Wiring Rules before a supply is connected. These rules aim at:-

      (i) Maintaining a high standard for the materials, fittings and equipment used, and

      (ii) Ensuring that the risks of injury to persons are reduced to a minimum.

   c. To ensure that an installation remains in a sound working condition, employing periodic tests. Such periodic testing may show up a progressively worsening condition. If good records are kept the equipment can receive attention before damage occurs.

2. Electrical faults may be of numerous types, but ultimate failure is due generally to:

   a. Broken conductor

   b. Breakdown of insulation

      (i) between conductor and earth,
      (ii) between conductors.

Test Equipment

3. When circuit tracing and fault finding a variety of testing devices are used, each of which has special advantages, and some definite limitations. The most common types of testing devices are described in the following pages.

4. **Neon "Test Pencil"** This is one of the most common test instruments, being both small and portable. It is also known as a 'phase pencil'. This tester can be very misleading; it will register a flow on a very small leakage current, but it does not necessarily indicate an adequate power supply. Hand-held electronic probes are available which detect the presence of a voltage without actually touching the live wire; one trade name is a 'Volt Stick'. These devices can be useful for detecting a live terminal, but they should not be relied upon to give a positive indication that no voltage is present if the terminal is to be touched. The absence of voltage should be confirmed with another device such as a multimeter.

5. **Incandescent Test Lamp** The test lamp is a simple testing device. It consists basically of a 240 V pilot lamp for testing the standard single-phase supply voltage or two 240 V 15-watt pilot lamps in series enabling the lamps to be used across 415 V. This type of test lamp does not give a positive indication that no voltage exists, so for isolation purposes, a more reliable tester should be used - such as a multimeter.

6. **Solenoid Operated Testers** These are far more reliable than "Test Lamps" and indicate the approximate voltage with a sliding pointer. They also indicate with an audible signal, (buzz), therefore it is not necessary to look at the tester, and hence divert attention from the live parts under test.

7. **Multi-Tube Neon's** These have the reliability of solenoid testers and have several tubes arranged to "strike" at various voltages, e.g. 100-110 V, 200-240 V, 400 and 500 V. A typical example is a "Martindale" brand and has spring-loaded insulated shrouds over the probes.

8. **Voltmeters** The voltmeter is another testing device that detects and indicates the magnitude or value of the e.m.f. in volts. It is placed between the points at which the voltage is to be measured and is normally referred to as being shunt or parallel connected. The instrument must be suitable for the supply (AC or DC) and be set on the correct range or voltage rating, for example, an attempt to measure 240 V with a 10 V instrument will usually destroy the meter movement, which is expensive to replace.

9. **Ammeters** The ammeter is an instrument that indicates current flow in the circuit. When connected in series with the load they indicate the value of load current. On AC circuits both voltmeters and ammeters may have their ranges extended by suitable voltage and current transformers respectively.

10. **Multi-Meters** For convenience, the functions of several measuring instruments are sometimes combined and incorporated in one instrument known as a multimeter. Many of them have AC and DC voltage and current ranges, and resistance ranges. The greater the variety of ranges the greater the cost.

11. **Resistance Measurement** When carrying out resistance measurements these values may be divided into two categories:-

    a. Low Resistance - earth continuity, heating element, motor winding.

    b. High Resistance - insulation resistance.

12. The type of value to be measured will govern the type of instrument to be used. Low current resistance devices are not a reliable instrument for checking the continuity of an earthing conductor.

13. **Example** The insulation resistance of a 240 V circuit must be measured under a voltage of 500 V d.c. The common types of multimeter rarely have a testing voltage of more than 9 V. The more comprehensive instrument as shown would be suitable for this test or a 500 V insulation tester. But, if these instruments were used to test a "solid-state" light dimmer or a smoke detector the device could be ruined. Some electronic components can be destroyed by the application of a potential as low as 4.5 V if the potential is applied incorrectly.

14. **High Voltage Insulation Testers** These are commonly referred to as "Meggers" although this is in fact, a brand name. Insulation Testers are usually rated at 500 V or 1000 V. Originally all insulation testers were hand-cranked DC generators, in recent years an alternative method has become popular which is the "transistorised" battery operated insulation tester. The insulation tester measures resistance values from about 10 000 ohms to infinity.

15. **Bridge Testing Instruments** These are highly accurate instruments often incorporating a conventional insulation tester that can be used to measure resistance as low as 0.01 ohms, up to 200 megohms (the latter as an insulation tester). These bridge instruments usually measure an unknown external resistance by the "Wheatstone Bridge" principle. In this, the meter, a galvanometer, reads zero when the unknown resistance is finally found. Earth faults in cables may also be detected and located by making Varley or Murray loop tests.

16. **Clip-on Ammeters** These instruments operate basically as a simple transformer. In most models, a range of current scales is provided and some have voltage ranges. Normal test leads and probes are required if the voltmeter function is used.

17. **Portable Appliance Testers** (PAT) These are intended for testing only those appliances with a three-pin plug connection and perform insulation tests and earth continuity tests. One trade name for such a device is a SAFE-T-CHECKER.

18. **Earth Continuity Tester** (Low voltage, high current). This instrument tests the earth continuity bypassing a heavy current (10 - 20 A) through the earthing conductor for a short time. If the flexible earth cable was hanging by a few strands, this test would destroy them without harming the appliance or cable, thus revealing a weakness not easily found in any other way. A Safe-T-Checker tests an appliance earthing conductor using a high current.

General

19. Regardless of the type of test being conducted, the tradesperson must be skilled in deciding:

    a. What to test for.
    b. What to test with.
    c. How to interpret the readings obtained.
    d. What constitutes a dangerous situation.
    e. What constitutes a situation where damage to equipment could occur.

3.11 - Appliance Testing

1. Many appliances are connected to the supply using a three core flexible cord and plug, and should the appliance or the wiring system be defective it is possible for anyone handling the appliance to receive a dangerous shock. The appliance must be periodically tested and checked to see that no live components are accessible to the user. AS 3760 - In-service Safety Inspection and Testing of Electrical Equipment details specific requirements for appliance testing. To ensure that the appliance is in satisfactory working order the following tests or checks must be conducted at regular intervals:

   a. Insulation resistance (test for earth faults).
   b. Continuity of all conductors (test for open circuits).
   c. The resistance of the earthing system.
   d. The polarization of the connections on the plug-top.
   e. Test for short circuits in the appliance.
   f. Visual check for electrical or mechanical damage or faults.
   g. Check the anchorage and integrity of all external cables.
   h. Check security and alignment of control knobs.
   i. Check controls, alarms and protective devices.

2. AS 3760 defines electrical equipment as Class 1 (single insulated) or Class II (double insulated). See Clause 1.4.

3. AS 3760 specifies that electrical equipment is to be inspected and tested before initial introduction to service, before return to service after a repair which could have affected the electrical safety, and at intervals not exceeding those specified in Table 4. Part of Table 4 is shown on the following page.

The frequency of Testing for Electrical Equipment

See AS 3760:2003, page 18 for the complete Table.

Type of Environment	Class 1	Class II (Inspection only)
Factories workshops and places of work of manufacturing, repair, assembly, maintenance or fabrication.	6 months	12 months
Environment where the equipment is subject to flexing in normal use.	12 months	12 months
Environment where the equipment is not subject to constant flexing of the supply cord.	5 years	5 years
Residential type areas of hotels, residential institutions such as motels and the like.	2 years	2 years
Hire equipment.	Before each hire	Before each hire

Isolation

4. Before any tests are conducted on plug-in appliances the appliance must be isolated from the supply by turning the switch off and removing the plug from the socket outlet.

Insulation Resistance

5. The insulation resistance in any single insulated appliance or device in which the working voltage between conductors and earth does not exceed 250 volts must be measured with a tester capable of applying a voltage of 500 volts d.c. between the conductors and earth during the test. A suitable hand-held test instrument is called a high voltage insulation tester. They are available in electronic or hand-wound types; one common type is known by the trade name of Megger.

6. **Method** Short circuit the active and neutral pins of the three-pin plug, connect the insulation tester between these pins and the earth pin. If the appliance incorporates an operating switch, make sure that it is ON.

7. **Reading** The minimum permissible value of insulation resistance is 1 megohm for single insulated (Class I) low voltage appliances, except for appliances that incorporate a sheathed heating element, in which case the minimum permissible value is 0.01 megohms (see AS/NZS 3000 Clause 8.3.6) and AS 3760 Table 2). In the case of double insulated (Class II) appliances, the minimum insulation resistance between any internal conductors and accessible metal parts is 1 megohm.

Active and Neutral Continuity

8. The active and neutral conductors from the plug top to the appliance terminal block (or equivalent) must be tested to ensure that they are electrically continuous. Any test instrument capable of indicating continuity in a low resistance cable can be used, including a multimeter, battery test lamp, Megger and ohmmeter.

9. **Reading** Any reading which indicates that the conductor is continuous means that the conductor can be regarded as satisfactory.

Internal Continuity

10. The resistance between active and neutral should be checked with a multimeter (usually on the ohms times 1 range) with the operating switch in the ON position. The multimeter should indicate the internal resistance of the appliance. A reading of zero ohms between active and neutral would indicate an internal short circuit. When the appliance operating switch is operated the reading should be infinity - indicating that the switch is operating correctly.

Continuity of the Earthing Conductor

11. The instruments used to test the continuity of the active and neutral conductors do not give a reliable indication of the condition of the earthing conductor because they do not pass enough current to adequately test it. If the earthing conductor is open-circuited a multimeter will correctly indicate a continuity fault. However, if the earthing conductor is hanging by just a few strands, a multimeter will incorrectly indicate a sound conductor. If the appliance was put into service and an active to earth fault developed, the earthing conductor may open the circuit before the circuit protection device operates, leaving the outer metal casing of the appliance alive.

12. The continuity of the earthing conductor can only be effectively tested using a portable appliance tester (PAT) which passes a current higher than that required to operate the circuit protection device which would be in the circuit under normal operating conditions. A commercially available device that meets this requirement is a Safe-T-Checker.

The resistance of the Earthing Conductor

13. The MAXIMUM permissible resistance of an earthing circuit must conform with AS/NZS 3000 Clauses 8.3.5 and Appendix B. The resistance of the earthing conductor in a single insulated appliance can be measured by connecting a suitable multimeter (set on the ohms times 1 range) between the earth pin on the plug top and the exposed metal frame of the appliance.

Visual Inspection

14. The following visual checks should be carried out on an appliance during the testing procedure, and faulty components should be replaced if applicable:

    a. Anchorage of the flexible cord.
    b. The physical condition of the flexible cord.
    c. The condition of the rubber or plastic sleeves on the flexible cord.
    d. The polarity of the connections on the plug-top.
    e. Correct colour coding or all conductors.
    f. The mechanical condition of the components.
    g. The tightness of terminations.
    h. Freedom from dust or dirt in ventilating openings.
    i. Operation of all controls.
    j. The condition of carbon brushes if applicable.
    k. Operation of all status indicators.

Operation

15. When all safety checks have been completed the appliance should be checked for correct operation at its normal rated voltage.

Documentation

16. It is a sound practice to keep a logbook in which the periodic safety checks on electrical appliances are recorded (see AS/NZS 3760 Clause 2.5). A sample inspection sheet is shown overleaf - it could be modified to suit any type of appliance or maintenance schedule.

INSPECTION SHEET

Type of Appliance: ______________________________ Date: _________________

Make: _______________________ Model: __________ Serial No: ____________

Inspected By: ____________________________ Owner: ______________________

	Good	NO Good	Action Required
1. The polarization of plug top			
2. Switch in active			
3. Continuity of Active & N			
4. Continuity of earth			
5. Security of earthing connection			
6. Insulation resistance			
7. Condition of flex			
8. condition of terminals			
9. Continuity and resistance of winding/element			
10. Colours of conductors			
11. Condition of safety covers			
12. Anchorage of flex			
13. Cleanliness of insulation between live parts			
14. Accumulation of dust/dirt			
15. Leads away from moving parts			
16. Porcelain beads sound			
17. Condition of reflector			
18. Condition of contacts			
19. Operation of moving parts			
20. Legibility of labels			

21. Control knob alignment				
22. Protective device rating				
23. Overall operation				
24. General points				

Actual insulation resistance (with switch on): ___________________________

Date next inspection due: ____

Remarks: ____

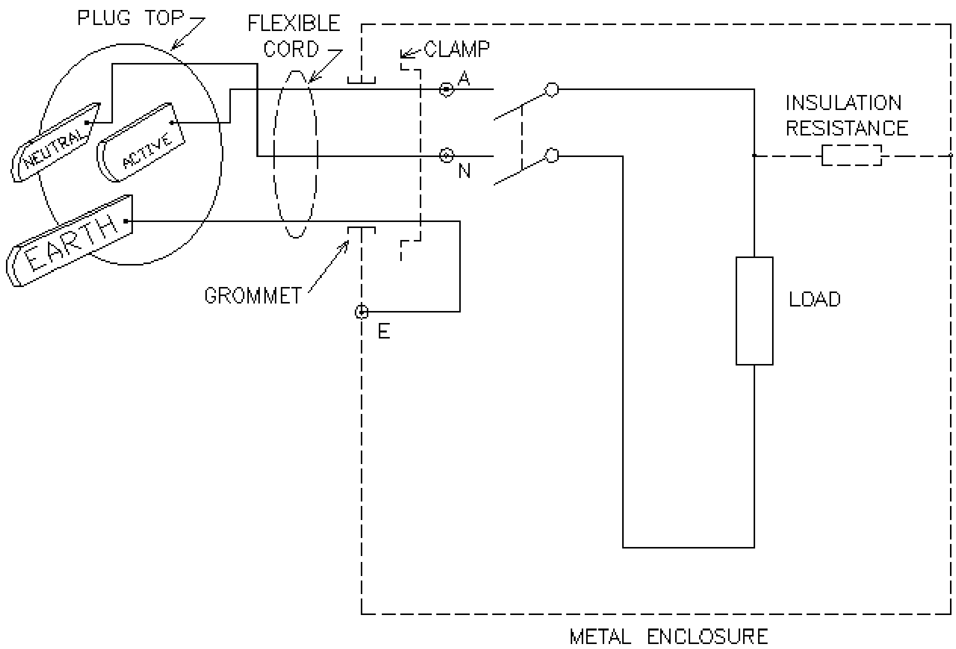
____

____

____

____

____



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North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-11	Version 4 2021

Appliance Testing

1. What is the minimum permissible insulation resistance in a single insulated 240-volt electrical appliance that does not incorporate a heating element?

2. What is the minimum permissible insulation resistance in a double insulated 240-volt portable electric drilling machine?

3. Why is a multimeter unsuitable for checking the continuity of the earthing conductor in an appliance?

4. What type of instrument must be used to measure the insulation resistance to earth in a single insulated 240-volt appliance?

5. At what voltage must the insulation resistance to earth in a single insulated 240-volt appliance be measured?

6. How must the three-pin plug-top on the flexible cord supplying a 240 volt single insulated portable appliance be polarized?

7. What measuring instrument should be used to check the active and neutral conductors for continuity in the flexible cord supplying a 240-volt appliance?

8. What is the trade name of a commercially available device that automatically tests most safety aspects of a 240-volt portable domestic appliance?

9. A particular 240-volt portable appliance is found to have a slightly damaged flexible cord - two internal insulated cores are exposed. Is it permissible to repair the cord by taping the damaged section of the cord with good quality insulating tape?

10. What precaution must be taken when testing insulation resistance to earth at the plug-top of a 240-volt portable appliance?

11. Is it permissible to secure the braiding on braided flex, where the flex enters a plug-top, by taping the braiding with insulating tape?

ANSWERS PAGE 243

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section	Summary 3.12	Version 4.1 2021

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3.12 - Protection of Wiring

4. The general requirements for the protection of wiring are:

a. Small overloads of short duration should not cause the protection to operate.

b. The protection must operate, even on a small overload, and if the overload persists long enough to cause overheating of the circuit conductors.

c. The protection must open the circuit before the damage caused by fault currents can occur.

d. Protection must be ‘discriminative’ in that only the faulty circuit is isolated and other circuits remain operative and unaffected.

Overload Protection

5. Overload protection is achieved by opening the circuit before overheating or deterioration of the protected wiring can occur.

Coordination

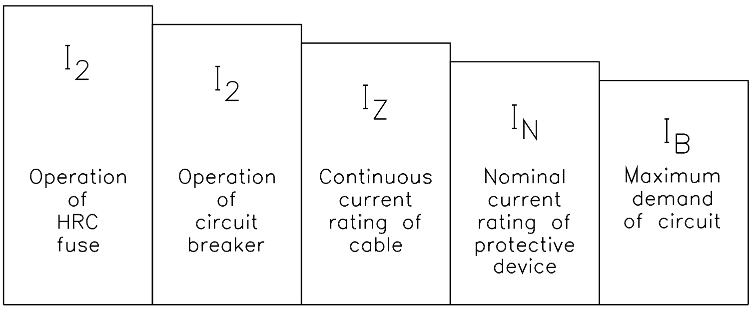
6. AS/NZS 3000 Clause 2.5.3.1 requires coordination between conductors and protective devices. The operating characteristics of a device protecting a cable against overload shall satisfy the following two conditions:

$I_B \leq I_N \leq I_Z$ (The symbol $\leq$ means ‘is less than or equal to’.)

$I_2 \leq (1.45 \times I_Z)$

Where:

I_B = Circuit maximum demand.
I_N = Nominal current of the protective device.
I_Z = Current carrying capacity of the cable.
I_2 = Current to operate protective device:
1.4 x I_N for circuit breakers or
1.6 x I_N for HRC fuses.



Short-circuit Protection

7. Short-circuit fault protection is achieved by

   a. The action of the fuse or circuit breaker being fast enough to open the circuit before the let-through energy can attain a value that would cause damage by overheating, arcing or mechanical stress; and

   b. The protective device is capable of opening the circuit, under these high fault current conditions, without damage to itself.

Short Circuit Current

8. In the case of a short circuit, the only limit to the value of current in the circuit is the impedance of the faulty circuit and the available short-circuit energy. This includes the impedance of the supply source, usually a distribution transformer provided by the network operator.

Transformer Impedance

9. The impedance of a transformer is usually stated as the percentage of the primary-rated voltage that is necessary to cause the full-load current in the secondary if the load terminals have a short across them.

10. A common transformer impedance value is 5 per cent. If 5% of the supply voltage will produce full load current, then, with a secondary short circuit and normal supply voltage of 100%, twenty times the rated full load current will be present.

$$Short\ circuit\ current = Full\ load\ current \times \frac{100}{Impedance\%}$$

The shorthand form of this formula is:

$$I_{SC} = I_{FL} \times \frac{100}{Z\%}$$

11. A distribution transformer having a full load current rating of 500 amps and an impedance of 5% would have a theoretical short circuit current of 20 x 500 or 10 000 amps. Since the heating effect of the current is proportional to the square of the current, doubling the current results in four times the heating effect. Currents of thousands of amps can result in explosions and catastrophic damage to the cables and related equipment.

Prospective Fault-current Levels

12. The rated full-load output current of a typical three-phase distribution transformer is given by the equation:

$$I_{FL} = \frac{kVA \times 1000}{\sqrt{3} \times V_L}$$

13. So the rated full load current of a 500 kVA, 415/240-volt three-phase distribution transformer with an impedance of 5% is:

$$I_{FL} = \frac{500 \times 1000}{\sqrt{3} \times 415}$$

= 695.6 A

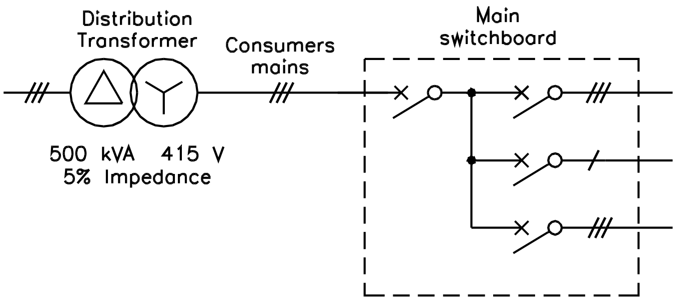
Prospective Fault Current

14. The available short circuit current (I_{SC}) if the 415 volts 500 kVA transformer had an impedance of 5% would be:

$$I_{SC} = I_{FL} \times \frac{100}{Z\%}$$

$$I_{SC} = 695.6 \times \frac{100}{5}$$

= 13 912 amps



Impedance/Phase of Supply

15. If the available short-circuit current of the 415 volts 500 kVA transformer was 13 912 amps, the supply impedance per phase (Z_1) would be:

$$Z_{Phase} = \frac{E_{Phase}}{I_{SC}} \quad Z_1$$

$$= \frac{240}{13912}$$

= 0.01725 ohms

16. The prospective fault current (I_F) per phase at the main switchboard is limited by the impedance of the supply plus the impedance of the cables from the source to the switchboard (the consumer's mains)(Z_2):

$$I_F = \frac{E_{Phase}}{Z_1 + Z_2}$$

17. The impedance of the consumer's mains can be found from the relevant tables if the cable size, type and length are known.

Cable impedance (ohms) - copper

Cutler Hammer

Nominal area of conductor (mm^2)	Nominal resistance of conductor at 20 °C	Length of cable - metres 5	10	15	20	25	30	40	50
1	0.01770	0.0885	0.1770						
1.5	0.01190	0.0595	0.1190	0.1785	Values above line reduce fault currents to less than 2 kA				
2.5	0.00720	0.0360	0.0710	0.1080	0.1443	0.1785			
4	4.52×10^{-3}	0.0226	0.0452	0.0678	0.0904	0.1130	0.1356	0.1808	
6	3.02×10^{-3}	0.0151	0.0302	0.0453	0.0604	0.0755	0.0906	0.1208	0.1510
10	1.79×10^{-3}	0.0090	0.0179	0.0269	0.0358	0.0448	0.0537	0.0716	0.0895
16	1.13×10^{-3}	0.0057	0.0113	0.0170	0.0226	0.0283	0.0339	0.0452	0.0565
25	6.60×10^{-4}	0.0033	0.0065	0.0099	0.0132	0.0165	0.0198	0.0264	0.0330
35	5.14×10^{-4}	0.0026	0.0051	0.0077	0.0103	0.0129	0.0154	0.0206	0.0257
50	3.79×10^{-4}	0.0019	0.0038	0.0057	0.0076	0.0095	0.0114	0.0152	0.0190
70	2.62×10^{-4}	0.0013	0.0026	0.0039	0.0052	0.0066	0.0079	0.0105	0.0131
95	1.95×10^{-4}	0.0010	0.0020	0.0029	0.0039	0.0049	0.0059	0.0078	0.0098
120	1.50×10^{-4}	0.0008	0.0015	0.0023	0.0030	0.0038	0.0045	0.0060	0.0075
150	1.22×10^{-4}	0.0006	0.0012	0.0018	0.0024	0.0031	0.0037	0.0050	0.0061
185	9.72×10^{-5}	0.0005	0.0010	0.0015	0.0019	0.0024	0.0029	0.0039	0.0049
240	7.40×10^{-5}	0.0004	0.0007	0.0011	0.0015	0.0019	0.0022	0.0030	0.0037
300	5.90×10^{-5}	0.0003	0.0006	0.0009	0.0012	0.0015	0.0018	0.0024	0.0030
400	4.61×10^{-5}	0.0002	0.0005	0.0007	0.0009	0.0012	0.0014	0.0018	0.0023
500	3.66×10^{-5}	0.00018	0.00037	0.0005	0.0007	0.0009	0.0011	0.0015	0.0018
630	2.83×10^{5}	0.00014	0.00028	0.0004	0.0006	0.0007	0.0008	0.0011	0.0014

Aluminium conductors have resistance values approx. 1.65 × copper.
Parallel cables – divide values by number of cables.

Ohms

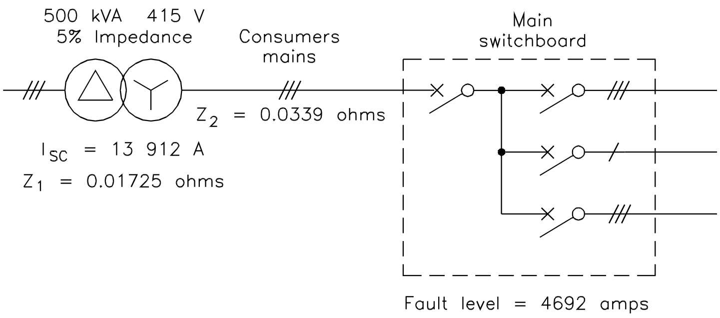
Fault Level at Main Switchboard

17. If the consumer's mains consisted of 30 meters of 16 mm^2 copper TPS cable the impedance of the active conductor (Z_2) would be approximately 0.0339 ohms per phase (from a Table). The prospective fault current level at the main switchboard would be:

$$f_{ault} = \frac{E_{Phase}}{Z_1 + Z_2}$$

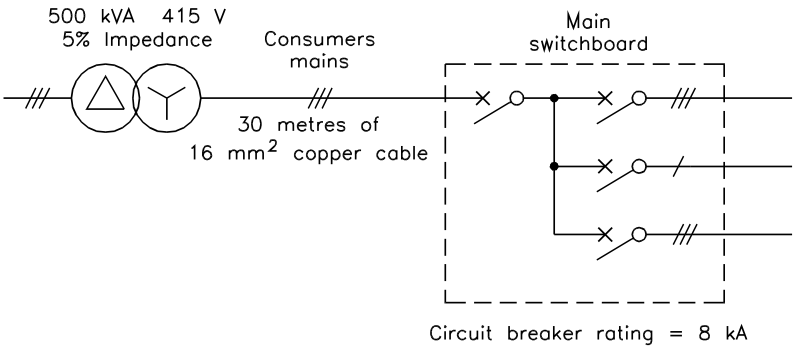
$$= \frac{240}{0.01725 + 0.0339}$$

= 4692 amps



Circuit Breaker Rating

18. Since the prospective fault current at the main switchboard is 4692 amps, the circuit breakers on the main switchboard need to be rated at a short circuit current at or above this value. A rating of 6kA would be suitable.



Equation Summary

$I_{FL} = \frac{kVA \times 1000}{\sqrt{3} \times V_L}$ (Transformer full load current)

$I_{SC} = I_{FL} \times \frac{100}{Z\%}$ (Transformer short circuit current)

$Z_{Phase} = \frac{E_{Phase}}{I_{SC}}$ Z_1(Supply impedance per phase (Z_1))

$I_F = \frac{E_{Phase}}{Z_1 + Z_2}$ (Prospective fault current at switchboard)

Fault Loop Impedance

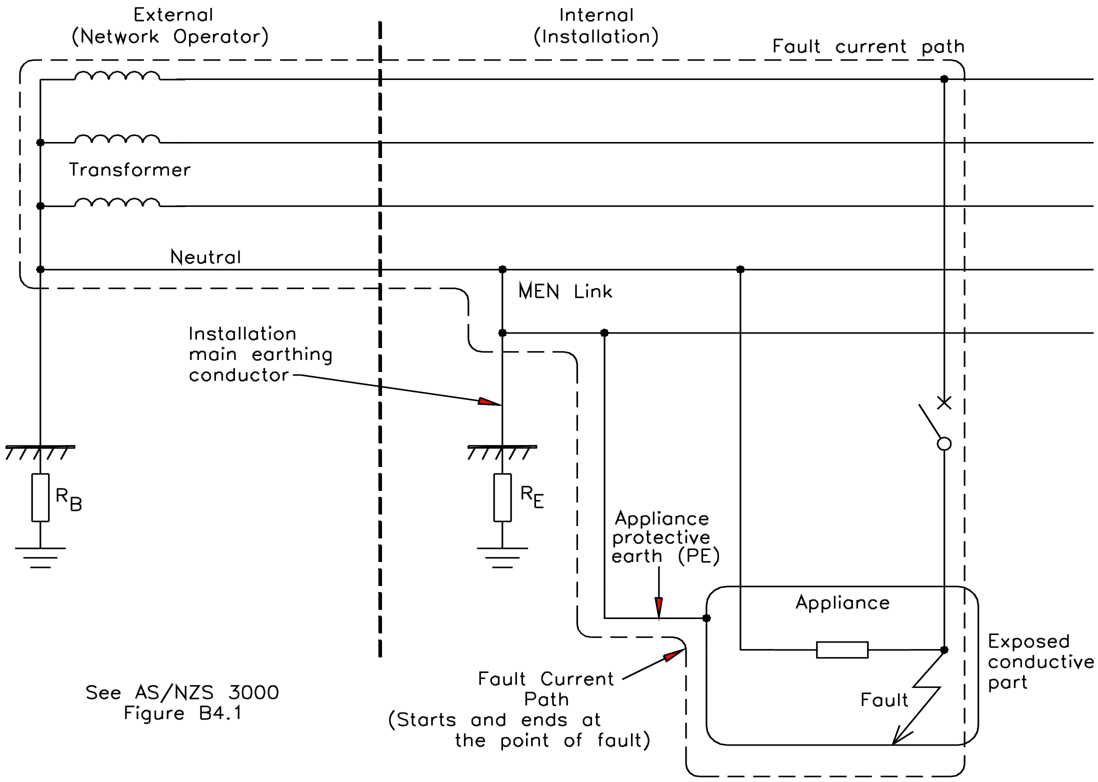
19. Fault-loop impedance is the impedance of the conductors in the series path taken by the current in the event of a fault between an active conductor and an earth fault, starting and ending at the point of the earth fault.

20. AS/NZS 3000 requires that each circuit is protected such that automatic disconnection of supply occurs within a specified disconnection time when a fault of negligible impedance occurs between an active conductor and a protective earthing conductor or an exposed conductive part anywhere in an electrical installation. See Clause 1.5.5.3(d).

21. This condition is satisfied when the fault-loop impedance is sufficiently low to allow enough current to flow in the fault-loop to cause the circuit protection device to operate within the specified time, thus limiting the touch voltage as required by Clause 5.7.4.

Fault Current Path (MEN)

22. The fault current path (or fault loop) in a MEN system starts and ends at the point of the fault. At the instant of the fault, current will flow through the fault loop and its magnitude is only limited by the total system impedance which is obtained from all of the individual impedances in the fault loop (see AS/NZS 3000 Clause B4.4).



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Disconnection Times

23. The maximum disconnection time for 230/240 V supply voltage shall not exceed the following (See AS/NZS 3000 Clause 1.5.5.3(d):

a. 0.4 seconds for final subcircuits that supply:

(i) socket-outlets having rated currents not exceeding 63 A; or

(ii) hand-held Class I equipment; or

(iii) portable equipment intended for manual movement during use.

b. 5 seconds for other circuits including sub mains and final subcircuits supplying fixed or stationary equipment.

Circuit Breaker Mean Tripping Time

24. The maximum value of fault loop impedance (Z_S) can be calculated for circuits protected by circuit breaker using manufacturers' information relating to the approximate mean tripping current for the circuit breaker. The mean tripping current for typical circuit breakers can be taken as:

Type B = 4 times rated current
Type C = 7.5 times rated current (e.g. general purpose loads)
Type D = 12.5 times rated current (e.g. high inductive loads)

See AS/NZS 3000 Clause B4.5 and Table 8.1 – note the 230 V.

Fault Loop Impedance Equation

25. The earth fault loop impedance (Z_S) for a circuit breaker can be determined using AS/NZS 3000 Clause 4.5 and Table 8.1:

$$Z_S \quad = \quad \frac{U_O \quad (The\ norminal\ voltage)}{I_a \quad (The\ mean\ tripping\ time)}$$

The maximum permissible values of measured resistance are given in AS/NZS 3000 Table 8.2 (see notes).

Fault Loop Impedance Calculation

26. A 240-volt final sub-circuit supplies a load consisting of a 10 A socket outlet protected by a 16 A, Type C, 8 kA circuit breaker. Determine the maximum internal resistance (R_{phe}) of the circuit, if the supply is not available.

$$Z_S = \frac{U_O}{I_a} = \frac{240}{16 \times 7.5} = 2 \text{ ohms (Clause B4.5)}$$

$$R_{phe} = Z_s \times 0.64 = 2 \times 0.64 = 1.28 \text{ ohms (T8.2 Note 1)}$$

Note: Table 8.2 is calculated using 230 V.
For 240 V multiply by a factor of 1.04.

Maximum Circuit Lengths - Table B1

27. Table B1 of AS/NZS 3000 contains maximum circuit lengths, above which the impedance of the conductors will limit the magnitude of the short-circuit current to a level below that required to operate the protective device protecting the circuit insufficient time (within 0.4 seconds socket outlets) to ensure safety against indirect contact.

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section	Review Questions 3.12	Version 4 2021

Protection of Wiring

1. What effects can it have on an electrical circuit if the maximum safe working current is exceeded?

2. List three of the general requirements for the protection of electrical wiring.

3. Which clause in AS/NZS 3000 specified the requirements for coordination between conductors and protective devices?

4. What two factors govern the value of current that can flow in a circuit if a 'short circuit' or 'bolted fault' occurs?

5. If a distribution transformer had an impedance of 5%, what value of short circuit current would flow if the full load secondary current was 100 amps per phase?

6. Calculate the rated full load current of a 350 kVA, 415/240-volt three-phase distribution transformer with an impedance of 5%.

7. Calculate the prospective short circuit current of a 350 kVA, 415/240-volt three-phase distribution transformer that has an impedance of 5%.

8. The network operator advises that the prospective short circuit current at the point of supply to a particular 415-volt three-phase installation is 10 000 amps. What is the supply impedance per phase?

9. Calculate the prospective fault current (fault level) per phase at the 3 phase 415 volt main switchboard if the impedance of the consumer's mains is 0.028 ohms and the specified impedance at the point of supply is 0.02 ohms.

10. When providing protection against indirect contact in a 240-volt installation, what is the maximum permissible disconnection time for final sub-circuits that supply 10 amp socket outlets?

11. When providing protection against indirect contact in a 240-volt installation, what is the maximum permissible disconnection time for a final sub-circuit supplying a fixed-wired air conditioning unit?

12. A 240-volt final sub-circuit supplies 10 amp socket outlets and is protected by a 16 amp Type C circuit breaker. Calculate the maximum internal fault-loop impedance of the final sub-circuit if the supply is unavailable.

13. List the internal and external parts of a MEN system that comprise the 'fault-loop' according to AS/NZS 3000. State the Clause number.

14. Determine the prospective short circuit fault current per phase at the main switchboard of an installation if the network operator gives the three-phase distribution transformer details as 415 V, 500 kVA, with an impedance of 4.9%. The impedance of the 16 mm^2 copper consumers mains is 0.4 ohms.

ANSWERS PAGE 244

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Summary 3-13	Version 4.1 2021

3.13 - Commissioning Installations

1. Commissioning of an electrical installation is the process of systematically checking to ensure that it allows safe operation, and all components operate as intended and according to specifications under all anticipated operating conditions. The electrical contractor is responsible for ensuring that all commissioning procedures have been carried out.

2. Some commissioning procedures may likely overlap those associated with inspection procedures (such as those involving checking the installation against the designer's installation schedules) but a major distinction is that commissioning is usually done with power applied. In larger installations commissioning is usually carried out using a pre-prepared checklist. These commissioning checklists are signed by the person responsible and are retained as part of the documentation for the installation.

3. Commissioning procedures must be effectively coordinated with others on the worksite. All required materials, plans, tools, instruments, specifications and schedules must be available during the process. Preparatory work must be checked to ensure that no unnecessary damage has occurred and complies with specified requirements such as statutory regulations, codes of practice, procedures and work instructions, quality assurance systems, manufacturers' specifications, circuit/cable schedules, customer/client requirements and national and state guidelines, and policies relating to the environment.

4. Any preparatory work must be checked to ensure that no unnecessary damage has occurred and complies with the specified requirements for the installation. All occupational health and safety policies and procedures must be followed such as work clearance procedures, isolation procedures, gas and vapour precautions, monitoring/testing procedures, use of protective equipment and clothing, risk assessment mechanisms and use of codes of practice. There must be no damage or distortion to the surrounding environment or services.

5. Circuits must be checked to ensure that they are isolated where necessary using specified testing procedures. Unplanned events or conditions must be responded to in accordance with established procedures such as work orders/instructions, reporting procedures, improvement mechanisms, compliance requirements, safety management and OH&S practices.

6. Final inspections and performance checks against specifications must be undertaken to ensure that the commissioning procedures include any equipment forming a part of the installation and used for a particular purpose.

7. Completion of the commissioning process must be reported to the supervisor under established procedures and may include verbal, written, electronic or recorded information. Commissioning usually occurs after all mandatory inspection and testing requirements have been met.

8. The following outline commissioning checklist indicates the types of activities that may be required before the installation is handed over to the owner.

Commissioning Checklist

Installation		Address	
Specification		Supervisor	
Electrician		Date	

Item	Operational Check	Remarks	Completed
1	Phase rotation at outlets		
2	Electric motor direction		
3	RCD check		
4	Isolating devices		
5	Lighting operation		
6	Power outlet operation		
7	Fire alarm systems		
8	Emergency lighting		
9	Public address systems		
10	Communication systems		
11	Data services		
12	Multiway lighting		
13	Emergency evacuation system		
14	Safety interlocks		
15	Signage		
16	Voltage drop		
17	Safety interlocks		

Signed: ______________________________________ ABC Electrics

Owner notified on ___________________________

North Metropolitan TAFE Electrical Trades	Electrical Fitting Revision Program (EFRP) EFRP Section 3	Review Questions 3-13	Version 4 2021

Commissioning Installations

1. Who is responsible for ensuring that commissioning has been carried out on an installation?
2. What is the general distinction between commissioning and testing an installation?
3. List three examples of general occupational health and safety policies that need to be followed during the commissioning process.
4. What type of unplanned event may occur that may require an electrician to respond by referring back to his/her supervisor during the commissioning process?

ANSWERS PAGE 246

References

- AS/NZS 3000 Wiring Rules
- Drawings courtesy of North Metropolitan TAFE Lecturing Staff.
- Photos courtesy of North Metropolitan TAFE Lecturing Staff

Typical Answers – Section 1

1.1 - Occupational Safety and Health Act

1. It is intended to ensure that you can work without being exposed to hazards. OS&H Act Clause 5.

2. It means that a person or employer has a legal responsibility to take reasonable care in matters relating to safety and health. Clause 19.

3. A workplace without hazards; provide information and training; consult safety representatives; provide protective materials; use safe processes. Clause 19.

4. Comply with instructions; Use protective equipment; Do not damage safety equipment; Report unsafe conditions; Report injuries. Clause 20.

5. To provide a safe workplace or to reduce, eliminate and control the hazards

6. Must work at the workplace; been employed for 2 years; have 2 years experience in similar work; had adequate training. Clause 31(8).

7. For an employee: A fine of $5000. Clause 54.

8. For an employer: A fine of $25 000. Clause 54.

9. An Improvement Notice and a Prohibition Notice. Clauses 48 and 49.

10. Attempt to remove the hazard - if possible; report the hazard. Clause 20.

11. The Occupational Safety and Health Act (1984)
    The Occupational Safety and Health Act Regulations (1996).

12. The Worksafe WA Commission.

13. Inspect; examine; enter; take; interview; photograph; record; measure in the workplace. Clause 43.

Typical Answers:

1.2 - Electrical Requirements of OSH Regulations

1. AS/NZS 3012 (3-58)

2. 3-59 (3-59)

3. An employer, the main contractor or a self-employed person or a person having control of the workplace. Penalty $25.000 (3-59)

4. 3-60 (3-60)

5. 3-60 (2)
   a. Does not exceed 32 volts alternating current.
   b. Is direct current.
   c. Is provided through an isolating transformer complying with AS/NZS 3108
   d. Is provided by the unearthed outlet of a portable generator. (3-60)

6. No. 3-61 (3-61)

7. Tag it and put it on his/her Licence Number. (3-62)

8. a. Provide the main contractor with a relevant record of testing.
   b. Ensure it is tagged and bears the worker's Licence No. (3-63)

9. a. No work to be done above overhead wires.
   b. No work to be done on or adjacent to a metal scaffold
   (i) that is less than 4.5 metres horizontally from; or
   (ii) that is less than 6 metres or below,
   overhead electric wires. (3-64)

10. a. 3-65
    b. The main contractor.
    c. By the time Plate Height is reached. (3-65)

Typical Answers:

1.3 - Industrial Safety

1. Yourself - the individual
2. The individual employee
3. A helmet and safety shoes or boots
4. Safety glasses; goggles or a face shield.
5. One square inside another.
6. Because it increases the risk of a person coming in contact with a live wire.
7. Ask your foreman or supervisor how it is used.
8. a. Approved helmet

    b. Safety glasses; goggles; face shield

    c. Earmuffs; approved earplugs

    d. Respirator; mouth mask

    e. Gloves

    f. Safety shoes or safety boots; spats

    g. Apron.
9. Assess the safety risk. (AS/NZS 4836:2011 Clause 2.1)
10. No. (AS/NZS 4836 Clause 2.1)
11. All workers involved in the task (AS/NZS 4836:2011 Clause 2.4)
12. To determine whether it is safe to perform a given task.
13. Considering each hazard, in turn, to eliminate or reduce the potential effects of each one.

    AS/NZS 4836:2011 Clause 3.1.1.
14. Identity. Isolate. Test. Tag. Lock-off.

Typical Answers:

1.4 - Lifting, Ladders and Special Situations

1. Something wrong with the ladder. Something wrong with the way it was used.
2. Stepladder.
3. Pole or straight ladder.
4. No makeshift repairs. No splits in rungs or stiles. No loose rungs. No rungs missing. Do not use metal or metal-reinforced ladders for electrical work.
5. The ladder must be the right type for the task. It must be long enough. It must be in first-class condition.
6. One metre (the ratio is one out of four up).
7. At least 5 rungs.
8. Tie to a structural part. Tie to an eyebolt. Tie to a heavyweight.
9. The base slipping out. The ladder falling sideways.
10. One foot on the ladder; one foot back; hold the styles; watch the climber.
11. In a haversack; belt (with the hands-free) or raise them on a rope.
12. Hinges secure. Cord secure and taut. 4 legs square and firm on the ground.
13. No.
14. The right way UP and the right way ROUND.
15. Aluminium ladders or pole ladders with wire strengtheners.
16. They can cause foot cramps or the foot can slip off.
17. The shoes can slip off the rungs.
18. Keep your back straight. Lift with your legs

Typical Answers:

1.5 - Electrical Safety in Installations

1. Test before you touch. Check the checker.
2. The outlet may be incorrectly polarised. The switch contacts in the outlet may be welded closed. Someone may switch it on.
3. No – test before you touch.
4. Switch off. Isolate. Tag. Test. Check
5. Another person must be present. Use all appropriate safety equipment

Typical Answers:

1.6 - Effects of Electric Shock

1. The victim stops breathing.
   The victim's heart stops or goes into ventricular fibrillation.
   The victim suffers severe burns.
   The victim suffers a traumatic shock to the nervous system.
   The victim may be unable to release his/her grip on a live machine.
   Damage to the eyes resulting from a flash.
2. The amount of current passing through the body.
   The path of the current through the body.
   The voltage of the circuit.
   The duration of contact with the live part.
   The resistance of the body at the time of contact.
   The surface area of the skin is in contact with the live component.
   The period of the cardiac cycle during which the shock occurs.
   The individual - some people are affected more than others.
3. An electric shock can also result in severe burns.
4. It is thought that there is a specific period during the cardiac cycle when the heart is most likely to be affected by an electric shock.
5. Comfort and reassure the person.
   Keep the person warm and quiet.
   Loosen tight clothing.
   Keep the person calm and confident of receiving help quickly.
   Arrange for the person to be treated by a doctor.
6. Shock to the nervous system (traumatic shock).
7. Ensure an abundant supply of fresh air.
   Loosen tight clothing and place the casualty in the COMA position.
   Cover the casualty but do not apply heat.
   Do not leave the casualty until help arrives.
   Do NOT attempt to give the casualty food or fluids.

Typical Answers:

1.7 - Rescue and Resuscitation

1. Yes.
2. No.
3. Airway - clear it
   Breathing - check and restore it
   Circulation - check and restore it.
4. No.
5. 2 inflations to 30 compressions.
6. About 1/3rd of the person's chest depth.
7. When the victim recovers or medical help takes over the responsibility.
8. Switch the electrical power off or safely remove the person from contact.

Typical Answers:

1.8 - First Aid Procedures

1. Lower the head and pinch the nose at the junction of bone and cartilage.
2. Apply pressure to the wound.
3. Traumatic shock (shock to the nervous system).
4. Loosen tight clothing.
   Keep victim quiet and warm.
   Reassure victim.
5. Remove victim to fresh air.
   Treat for traumatic shock.
   Seek medical assistance.
6. Telephone 112.
7. Because there is always the risk of infection.
8. Further damage can be caused to the throat passages by vomiting.
9. Tetanus.
10. Hold the burn under clean cold running water.
11. Flush the eyes with plenty of water.
12. The eyes. Flush them with water immediately.
13. Loosely bandage BOTH eyes if the casualty agrees.
14. Switch the machine off and render first aid.

Typical Answers:

1.9 - Fire and Chemical Hazards

1. Fuel. Heat. Oxygen.
2. Spontaneous combustion.
3. No.
4. Raise the alarm.
5. Wood; cloth; paper - solid flammable materials.
6. Flammable liquids.
7. Burning gases.
8. Electrical equipment.
9. Fires involving cooking oils and fats
10. Water.
11. Carbon dioxide.
12. Crawl with the mouth and nose as close to the floor as possible.
13. A type that has water as the extinguishing agent.
14. Water can splash the liquid and spread the fire.
15. Yes – it contains a vapourising liquid.
16. Telephone 112.
17. Smoke and fumes can cause suffocation.
18. See that your escape route is clear.
19. Close the door to contain the fire and reduce the oxygen flow.
20. Carbon dioxide.
21. The horn can get very cold and cause frostbite.
22. Dry powder.
23. Dry powder chemical extinguishers;
24. Carbon dioxide. Dry chemical. Vapourising liquid.
25. Material Safety Data Sheets.

Typical Answers:

1.10 - Danger Tag Procedures

1. Red and black.
2. Yellow and black.
3. Securely attached to the isolating switch or valve at the origin of the subcircuit or equivalent.
4. Yes.
5. Your name; your department and the date.
6. The person who put it there.

Typical Answers:

1.11 - Isolation of Supplies

1. Switch the appliance off; Switch the appliance off at the socket- outlet; Remove the plug from the socket-outlet.
2. Identify the equipment. Switch the device off; Isolate it; Attach a red danger tag to the isolating switch; Test for zero volts; Check the checker.
3. Tape them up and make them safe. See also Wiring Rules.
4. An air circuit breaker (ACB).
5. Written isolation procedure to be used by others.

Typical Answers – Section 2:

2.1 - Sources of EMF

1. Thermocouple, Magnetic/Mechanical, Friction, Chemical, Light, Pressure
2. Heat, Light, Sound, Force
3. A.C: - The voltage is constantly changing in magnitude and polarity.
4. D.C: - Supply is one in which the polarity of the supply remains constant.
5. Galvanic corrosion occurs when two dissimilar metals are touching and are either in the air or a liquid.

Typical Answers:

2.2 - Ohm's Law

1. Source (power supply), Conductors (wires) and load (lamp/heater)
2. Circuit protection (fuse/circuit breaker) and Control (switch)
3. 24÷3 = 8 amps
4. 12÷6 = 2 ohms
5. 10 x 5 = 50 volts
6. 20/2000 = 0.01 amps or 10 milli amps
7. 40/0.002 = 20 000 ohms or 20 kΩ
8. 1 000 000 x 0.000 020 = 20 volts

Examples for Practice Answers

a) 4 amps
b) 0.5 ohms
c) 25 volts
d) 0.003 amps or 3mA
e) 20000 ohms or 20 kΩ
f) 50 volts

Typical Answers:

2.3 - DC Series Circuits

1. Disconnect one resistor - If the circuit resistance becomes infinite then they are connected in series but if the resistance increases when the circuit is connected in parallel
2. 10 + 20 + 30 + 40 = 100Ω
3. 6 + 4 + 10 = 20 Ω
4. The currents are the same through each component
5. The sum of the voltages across each component is equal to the supply voltage
6. No
7. The total resistance will always be greater than any single resistor
8. 60 volts
9. Rt = 100 Ω $P = I^2 \times R$ $2^2 \times 100 = 400$ watts
10. Volt drop, voltage drop or fall in voltage
11. 24 ÷12 = 2 amps
12. Vr1 = 2 x 2 = 4 V   Vr2 = 2 x 4 = 8 V   Vr3 = 2 x 6 = 12 V
13. 10 volts
14. One lamp being short-circuited
15. 0 volts
16. One
17. The current would also be halved
18. Infinity (open circuit)
19. The lamp with 240 volts measured across it is an open circuit

Typical Answers:

2.4 - DC Parallel Circuits

1. 2 Ω
2. Disconnect one resistor - If the circuit resistances increases then they are connected in Parallel, but if the resistance goes to infinity then the circuit is connected in series **or** if one resistor is disconnected the rest of the circuit still operates
3. 1 Ω
4. The voltage is the same across all parallel resistors
5. The sum of the individual currents is equal to the total current (Line) flowing in the parallel circuit
6. No
7. The total resistance is always lower than the value of the smallest resistor
8. 22 amps (I_{R1}=12 A, I_{R2} = 6 A, I_{R3} = 4 A)
9. 4000 watts (Rt = 10 Ω, E = 200 V)
10. 14 amps

Answers to Exercises

a) 0.999 Ω
b) 24.91 Ω
c) 0.0096 Ω
d) 50 Ω
e) Decrease
f) 1.5 Ω and 384 watts

Typical Answers:

2.5 - DC Series/Parallel Circuits

1. 24 Ω
2. The total resistance will decrease
3. From Circuit 1

	R	I	V	P
R_1	100 Ω	0	0	0
R_2	120 Ω	2 A	240 V	480 W
R_3	80 Ω	1 A	80 V	80 V
R_4	160 Ω	1 A	160 V	160 W
R_5	100 Ω	0	0	0

Line	80 Ω	3 A	240 V	720 W

Typical Answers:

2.6 - The A.C. Waveform and Phasors

1. There must be relative movement between them. Conductors crossing lines of flux
2. Zero volts. There is no relative movement
3. An alternator
4. The frequency increase
5. Hertz or Cycles per second
6. Hertz means cycles per second
7. When the conductors cross the lines of flux at right angles
8. 50 Hz
9. **f** for frequency
10. Hz for Hertz
11. Peak, RMS (root means square), Average, and Peak to Peak
12. 141.44 volts peak
13. 70.7 volts DC
14. 0.707 of Peak
15. 0.637 of Peak
16. 679 volts approx peak to peak
17. 339.46 volts peak
18. RMS
19. Zero volts

Typical Answers:

2.7 - Power Factor

1. Apparent power is $V_Z \times I_Z$ 240V x 10A = 2400 VA
2. The reading of the wattmeter i.e. 2000 Watts
3. 6545 VA_R
4. Power Triangle as per notes.
5. True power ÷ Apparent power P/S or Watts/Volt-Amps.
6. 1 or unity, CosΘ cannot be greater than 1
7. Voltmeter, Ammeter and Wattmeter.
8. 0.83 lagging
9. The circuit draws a higher line current, therefore, everything connected with the supply would need to be larger. (Higher current carrying capacity.)
10. Connecting a capacitor in parallel with the inductive components.
11. Short circuit the capacitor terminals to ensure it is not charged.
12. 0.5 microfarads AS/NZS 3000 clause: 4.15.3.1
13. The power factor would be lower than if the motors were running at higher loads.
14. According to the Western Australian Distribution Connections Manual, 0.8 lagging to 0.8 leading.

Typical Answers:

2.8 - Electrical Reticulation

1. 415/240 or 400/230 volts, three-phase four-wire. Multiple Earthed Neutral (MEN).

2. 50 cycles per second (50 Hz).

3. High voltages can cause electrocution without actually coming in contact with a live part.

4. No – special training is required.

5. Any voltage above 1000 volts. See AS/NZS 3000 Clause 1.4.98 (c)

6. Energy Safety

7. The electric current passes through a body when that body touches

   one or more accessible parts of live electrical equipment. (AS/NZS 3000 Clause 1.4.94)

8. A voltage appearing between simultaneously accessible live parts under indirect contact fault conditions. (AS 2067 Clause 3.9.6 and AS/NZS 3000 Clause 1.4.95).

9. Creepage distance. The shortest path between two conductive parts, or between a conductive part and the bonding surface of the equipment measured along the surface of the insulating material (AS/NZS 3100 Clause 2.1.17)

10. The voltage between left and right feet when spaced 900 mm apart."

11. Signs; Labels; Barriers; Components; Location etc.

12. Switching/Isolation procedures; Earthing of equipment during maintenance;
    Erection of barriers; Restricting access; Placement of safety signs and labels;
    Separation of HV and LV systems; Control and indicating equipment;
    Circuit protection devices etc.

13. AS/NZS 3000 Clause 7.6

14. WAER Section 7.

Typical Answers:

2.9 - Regulatory Requirements

1. Section 1.
2. No.
3. Section 5.
4. Section 6.
5. AS/NZS 3008.1.1:1998.
6. WA Electrical Requirements (Section 12).
7. The Mines Safety and Inspection Regulations (1995).
8. 50 volts. (Except for supply authority line workers).
9. In-service safety inspection and testing of electrical equipment.
10. Electrical Installations - Construction and Demolition Sites
11. Electricity (Licensing) Regulations 1991.
12. 'Shall means it is mandatory (compulsory). 'Should' means that it is a recommendation - but it is not mandatory.
13. Yes.
14. WA Electrical Requirements, Section 10.

Typical Answers:

2.10a - Protection Principles and Earthing

1. To provide a mechanism for automatically disconnecting the supply in the case of an earth fault.
2. Exposed conductive parts
3. 2.5 metres
4. No
5. Green/Yellow Table 3.4
6. Insulation; barriers or enclosures; obstacles; out of reach.
7. AS/NZS 3000 Figure B4.5

Electrical shock and excessive temperatures from direct or indirect contact.

Typical Answers:

2.10b - Earthing Requirements

1. No. AS/NZS 3000
2. One square inside another.
3. No. AS/NZS 3000 Clause 5.5.2.2.2
4. By connecting a flexible conductor between the fixed component of the cubicle and the door. Clause 5.3.2.3(c)
5. Yes. Clause 5.3.2.3(c)(iii)(B)
6. No. Clause 5.5.6.2 (d)
7. The electrical connection of non-electrical metallic piping to the main earth in an installation. AS/NZS 3000 Clause 1.4.52

Typical Answers:

2.11 - Electrical Diagrams

1. All components are drawn in a de-energised condition
2. Power Conductors
3. Wiring Diagram
4. A circuit diagram (schematic)
5. Wiring Diagram
6. Circuit diagram
7. Circuit Symbols
    a. the symbol for the stop button
    b. symbol for fuse
    c. the symbol for relay contact n/o
    d. the symbol for the relay coil
    e. the symbol for thermal o/l heater element
8. Architectural Symbols
    a. Main Switch Board
    b. flood light
    c. twin fluorescent
    d. double socket outlet (GPO)
    e. intermediate switch

Typical Answers – Section 3

3.1 - Single-phase Transformers

1. No
2. Primary and secondary windings
3. Secondary
4. 180 degrees out of phase
5. Double Wound Transformer
6. Primary
7. Secondary
8. Step-up transformer
9. Laminated steel (Stalloy)
10. Core and Shell type
11. Ferrite
12. Tapped secondary or Autotransformer
13. Eddy current, Hysteresis, and Copper Losses
14. Isolation transformer
15. Primary
16. To isolate the secondary output voltage from the earth
17. The output voltage would reach dangerously high values (9600 V approx)
18. 5 kVA
19. 60 volts
20. 6 to 1
21. When under full load
22. 100 turns
23. 30 amps
24. 0.17 amps
25. 1 to 20
26. 40 to 1
27. High Voltage Insulation Tester (Megger)
28. There are 100 turns on the secondary. The secondary voltage would be approx 63 volts on the 380 turns tapping

Typical Answers

3.2 - Single-phase Split-phase Motors

1. A single-phase split-phase motor has two distinct windings, a start and a run.
   In a three-phase motor, the sets of windings and poles are all similar.

2. A squirrel cage rotor.

3. 2 windings – start and run.

4. A centrifugal switch.

5. 240 volts.

6. 2 – 2.5 amps.

7. The switch is closed when the motor is stationary.

8. Reverse connections of either run or start winding, but not both.

9. The run winding.

10. The resistance of the start winding is higher than the run winding.

11. On the outside of the carcass or inside the end shield.

12. The centrifugal switch.

13. 4 ohms. The windings are connected in parallel and the switch has very little resistance.

14. The centrifugal switch opens.

15. 1500rpm – slip. Slip typically 4-5% so 1425 – 1440rpm

16. A cap start motor has a capacitor and a larger diameter start winding than equivalent split-phase motors.

17. Diagram.

18. Diagram.

19. Split-phase, capacitor start, capacitor start and run and permanent capacitor motor.

20. The centrifugal switch.

21. The synchronous speed.

22. More starting torque.

23. Reverse connections of either run or start winding, but not both.

24. The centrifugal switch disconnects the run winding when the motor reaches about 75% full speed.

25. The start winding will burn out, possibly in less than 30 seconds.

26. 12 ohms.

27. An electrolytic capacitor.

28. Approx. 150 microfarads.

29. Starting torque is measured in Newton-meters (Nm).

30. 8 ohms, the capacitor would prevent measuring the start winding.

31. The start winding would stay connected and would overheat, this would probably burn the winding out.

32 Permanent capacitor motor. 2 directions

33. Split-phase motor.

34. A capacitor start motor

35. Permanent capacitor motor. 1 direction.

36. Capacitor start capacitor run motor.

Typical Answers

3.3 - Three-phase Transformers

1. Diagram – Star Delta
2. 138.6 volts (approx.)
3. Check the voltage between the closing connections. It should be zero volts
4. Primary winding
5. One winding is reversed
6. High Voltage Insulation resistance tester (Megger) 500 volts
7. Core type
8. Diagram
9. Star – Delta 318 volts
   Delta – Star 953 volts
10. Line Current = 125 amps
    Phase Current = 72.2 amps

Typical Answers:

3.4 - Transformer Testing

1. Loose laminations, Oil leaks, Loose terminals, Condition of windings, Conditions of supports and mountings, Overheating on no load

2. The windings are electrically continuous and usually tested with a multimeter or ohmmeter on low ohms

3. The low resistance (15 Ω) is the Primary and the high resistance (90 Ω) is the Secondary winding. The testing can be carried out with a multimeter on low ohms scale.

4. Earth faults, Interwinding faults, Shorted Turns, Open Circuits, Incorrect connections

5. Ohmmeter or external grower

6. High Voltage Insulation Resistance Tester (Megger)

Typical Answers:

3.5 - Three-phase Motor Construction & Connections

1. Totally enclosed, totally enclosed fan cooled, flameproof, enclosed ventilated or open and drip-proof.
2. Yoke, stator, stator winding, rotor, rotor windings, bearings, foot or flange mounting, bearings, end shields, cowl, terminal box, lubrication points, cable entries, pulley or coupling and bearing caps.
3. The rotor.
4. Squirrel cage induction motor (SCI motor).
5. The nameplate.
6. The drive end and non-drive end.
7. Totally enclosed fan cooled.
8. Star and delta.
9. 415 volts.
10. 400 volts.
11. Three
12. Three
13. The stator winding.
14. No.
15. By reversing any two incoming line leads.
16. Delta.
17. A, B and C
18. A_1, B_1, C_1 and A_2, B_2, C_2
19. Yes.
20. U, V and W or X, Y and Z
21. U_1, V_1, W_1 and U_2, V_2, W_2 or X_1, Y_1, Z_1 and X_2, Y_2, Z_2
22. NO. Clause 5.5.6.2 dii
23. No.

24. Four, 3 lines and earth.

25. To keep the touch potential below 50 volts by interrupting the supply under earth fault conditions.

Typical Answers:

3.6 - Three-phase Induction Motor Operation

1. 1440 RPM.

2. No. It could continue to run if the fault occurred during operation and continue to run. If the load exceeds 57% the motor could burn out.

3. Two times the power rating in kilowatts.

4. The three-phase rotating magnetic field, also known as electromagnetic induction.

5. By reversing any two of the incoming line leads

6. Cast Aluminium.

7 Rotors slots are skewed to reduce magnetic noise and improve starting characteristics.

8. Insulation resistance to earth – minimum 1 megohm with a megger set at 500 volts

9. It is not possible unless we increase the supply frequency or drive the motor externally.

10. Greater starting torque.

11. 1000 rpm (6 poles at 50 Hz)

12. The rotor winding must be less than synchronous speed to cut flux to produce the torque to overcome friction and windage.

13. 18 amps are the current in each phase when the motor is running on full voltage and full load.

14. The speed of the rotating magnetic field.

15. Yes. Speed is proportional to frequency.

16. No, the coil voltage would be too high.

17. (frequency x 60) / pairs of poles or (frequency x 120) / poles

18. 1420 rpm on full load.

19. Rotor frequency is 50 Hz when the rotor is stationary when the motor is first switched on.

20. The frequency, the number of poles and the load on the motor.

21. Approx. 1595 rpm, just under synchronous speed.

22. Just under 1500 rpm, the same as in star.

23. Just under 1500 rpm, the same as in the alternate direction.

24. F – standard three-phase SCI

25. A – double cage rotor.

26. E - Three-phase high resistance motor starter.

27. B – Three-phase wound rotor motor.

28. No effect on the direction of rotation.

29. Three.

30. The resistance of the rotor circuit would be at its lowest value.

31. Connect the line to the stator terminals and short circuit the rotor terminals.

32. About 150 volts.

33. At the instant, the motor is switched on.

34. Six, three for the rotor and three for the stator.

35. The stator winding.

36. No, there must be a circuit for currents to be induced in the rotor.

37. By varying the resistance in the rotor circuit, maximum speed occurs when the resistance of the motor circuit is lowest.

Typical Answers:

3.7 - Three-phase DOL Motor Starters

1. A magnetic DOL starter
2. Yes – with a suitable transformer
3. O/L contacts should be connected in series with the contactor coil
4. Yes
5. 50 amps
6. Magnetic Contactor, Thermal Overloads, Stop/Start station
7. DOL starters result in the highest starting current
8. DOL starters result in the highest starting torque
9. WAER section 3.5.2 Electrical inrush current

Star Delta Starter

1. Manual and Automatic
2. A1,B1,C1, A2, B2, C2,
3. L1, L2, L3
4. R, S, T
5. A six terminal Squirrel Cage Induction motor
6. When one phase is lost
7. 240 volts (415 ÷ √3)
8. Reduced starting torque
9. To reduce the line current on startup
10. Six
11. Contacts A1 and A2, B1 and B2, C1 and C2 are bridged

Primary Resistance Starters

1. Magnetic Contactors, Large resistors, Time delay relays, Overload mechanism, Stop/start station
2. The motor must be connected to Delta – usually at the terminal block
3. A primary resistance starter requires a 3 phase motor with at least three line terminals - ABC or UVW
4. Three - usually marked L1, L2, L3 or R, S, T
5. Usually a primary resistance starter. It is cheaper than an auto-transformer or electronic starters
6. Reduce the transient current when switching. PR starters do not momentarily cut the supply during the transition from start to run
7. SIX – two in series with each of the incoming lines
8. Because the motor remains connected to the supply during the transition period.
9. No – primary resistance starters can only be used to start motors on very light or no load

Autotransformer Starters

1. Starting current is limited by reducing the voltage during starting
2. Magnetic contactor, Transformer, Time delay relay, overload mechanism, and stop/start station
3. Three motor terminals A1, B1, C1
4. Three incoming terminals L1, L2, L3
5. Autotransformer starter – higher voltage tapping can be used
6. Two coils connected in an open delta
7. 50%, 60%, 65%, 80%

Secondary Resistance Starters

1. To prevent the starter from being started if the rotor resistor is shorted out
2. A, B, C
3. By reversing any TWO incoming lines
4. Six (3 stator and 3 rotor leads)
5. No effect on the direction of rotation
6. Three slip rings
7. Lowest value
8. Greater starting torque and simple speed control
9. D, E, F
10. Six terminals
11. Three brushes

Typical Answers:

3.8 - Lamps

1. The power rating in watts
2. The hot resistance is approximately 12 times the cold resistance
3. GES – Goliath Edison Screw
4. A Quartz Halogen (or tungsten filament) lamp
5. The outer glass envelop has cracked while the lamp was operating
6. a) The lamp has reached the end of its useful life

   or

   b) It has been subjected to higher than designed operation voltages
7. In an ES lamp holder, the neutral must be connected to the outer contact (AS/NZS 3000 Clause 4.5.1.2)
8. It has a low efficiency (most of the electrical energy is to produce heat)
9. They must have a current limiting device – usually a ballast
10. The stroboscopic effect can result in the rotating machine appearing to be stationary or rotating slower than its actual speed
11. The type of gas used inside the neon lamp
12. Neon lamps normally have a leakage transformer to provide the high operating voltage and to limit the line current
13. Low-pressure sodium vapour lamps give off a yellow light
14. A power factor correcting capacitor
15. Do not break the glass, allowing the sodium to come into contact with water as it will explode
16. Mercury vapour gives off a bluish light
17. The UltraViolet given off by the arc tube will damage your eyes
18. Self-ballasting mercury vapour lamp does not require any auxiliary equipment
19. Ballast, Igniters, and a power factor correcting capacitor
20. Blended MV lamp is self-ballasting therefore does not require a current limiting component because of the tungsten filament

Typical Answers:

3.9 - Fluorescent Lighting

1. 18/20 watt – 600 mm, 36/40 watt – 1200 mm, 65/80 watt – 1500 mm
2. Ballast
3. No effect on the operation but the increase in current
4. Open Circuit
5. Faulty starter
6. Diagram of 2 x 18 W fluorescent tubes controlled by 36 W ballast
7. Limit current after startup and provide an inductive kick to the tube at startup
8. Frequent starting will reduce the useful life of the lamp
9. Capacitor
10. Lead-Lag ballast circuit or two fluorescents on different phases

Typical Answers:

3.11 - Appliance Testing

1. 1 megohm.
2. 1 megohm.
3. Because it does not provide enough current to reliably test the earthing conductor - e.g. if it was hanging by 1 strand.
4. A Megger or 500-volt high voltage insulation tester.
5. 500 volts d.c. (AS/NZS 3000 - Clause 8.3.6)
6. Earth; Active; Neutral when viewed from the back of the plug-top.
7. A multimeter is suitable.
8. A Safe-T-Checker.
9. No. The cord will need to be replaced.
10. The conductors must first be tested for continuity - and the operating switch on the appliance must be on.
11. No. The braiding must be WHIPPED with a strong thin cord.

Typical Answers:

3.12 – Protection of Wiring

1. Overheating, damage caused by arcing, damage caused by magnetic stresses, physical damage to cables and components.

2. Small overloads of short duration should not cause the protection to operate. The protection must operate, even on a small overload, and if the overload persists long enough to cause overheating of the circuit conductors, the protection must open the circuit before the damage caused by fault currents can occur. Protection must be 'discriminative' in that only the faulty circuit is isolated and other circuits remain operative and unaffected.

3. AS/NZS 3000 clause 2.5.3.1

4. The supply voltage and the fault loop impedance. $I = V/Z_s$

5. 2000 amps.

6. 486.92 amps.

7. 9738.44 amps.

8. 0.024 ohms.

9. 5000 amps.

10. 1.5.5.3 (d)i 0.4 seconds.

11. 1.5.5.3 (d) ii 5 seconds.

12. 230/(7.5x16) = 1.917ohms (see table 8.1) Values obtained must be measured with an appropriate fault loop impedance meter with supply on.
    In table 8.2 we first de-rate the impedance value by 0.8 to allow a conductor temperature of 20 degrees and by 0.8 supply voltage to allow for the supply transformer impedance. 0.8 x 0.8 = 0.64 so 0.64 x 1.917 = 1.226 (see table 8.2) and we can measure this with a suitably calibrated meter capable of measuring ohms when the supply is not available.

13. The protective earth, the entire neutral return path, the supply transformer's neutral to the star point and all associated actives from the supply active through the distribution system to where the fault occurs.

14. $I_{FL} =$ KVA x 1000/($\sqrt{3}$ x V_L) = 695.60 amp $I_{SC} = I_{FL}$ x 100/Z% = 14195.92 amps

    $Z_1 = E_{Phase} / I_{sc}$ = 0.0169 ohms $I_{FL} = E_{Phase} /(Z_1 + Z_2)$ = 575.68 amps

Typical Answers:

3.13 - Commissioning Installations

1. The electrical contractor.

2. Commissioning involves ensuring correct operation.
   Testing involves using instruments to ensure that mandatory and specified technical requirements have been met before power is applied.

3.
   Work clearance procedures.
   Gas and vapour precautions
   Use of protective equipment and clothing
   Risk assessment mechanisms
   Isolation procedures.
   Monitoring/testing procedures.
   Risk assessment mechanisms

4. If a device is installed which does not meet the specifications.