Government of Western Australia
North Metropolitan TAFE

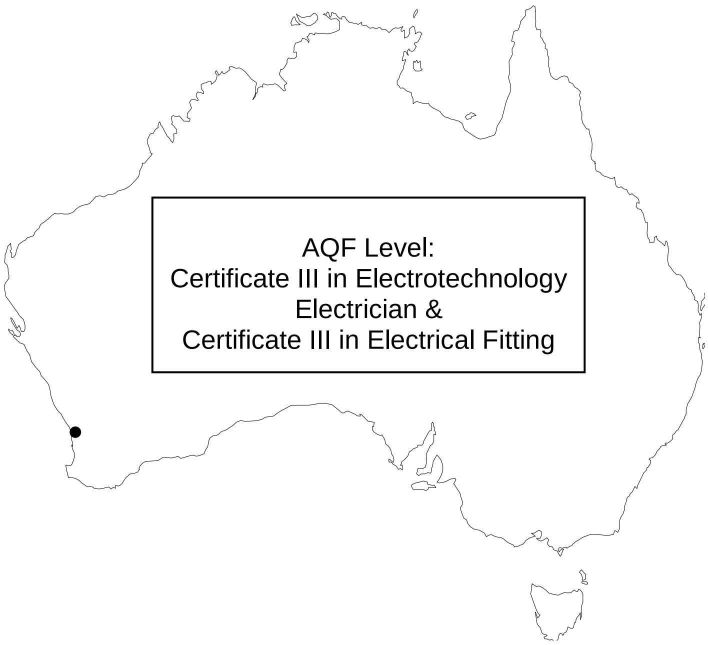
UEE 11 Training Package Support Material
(Non-Endorsed Component)

Based on:
National Electrotechnology Industry Standards

Resource Book

UEENEEG033A

Solve problems in single and three phase low voltage electrical apparatus and circuits



AQF Level:
Certificate III in Electrotechnology Electrician &
Certificate III in Electrical Fitting

North Metropolitan TAFE
Revised
August 2018

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UEENEEG033A Solve problems in single and three phase low voltage electrical apparatus and circuits

C O N T E N T S

Training Achievement Record

Name:	Student No:	App No
Employer:		College:

Activity		Date	Lecturer
Worksheet 1A-1	Fixed electrical heating appliances		
Worksheet 1B-1	Electrical heating control devices		
Activity 1B-2	Single pole three heat switch		
Activity 1B-3	Double pole three heat switch		
Activity 1B-4	Simmerstat		
Worksheet 1C-1	Electrical water heater operation		
Worksheet 1D-1	Text book questions		
Worksheet 2A-1	Lighting concepts and incandescent lighting		
Worksheet 2A-2	Lighting concepts and incandescent lighting		
Activity 2A-3	Incandescent lamps		
Worksheet 2B-1	Fluorescent low intensity discharge lighting		
Activity 2B-2	Fluorescent lamps		
Activity 2B-3	18 W twin lamps		
Worksheet 2C-1	High intensity discharge lighting		
Activity 2C-2	Low pressure sodium lamps		
Activity 2C-3	High pressure sodium lamps		
Activity 2C-4	Mercury vapour lamps		
Activity 2C-5	Metal halide lamps		
Worksheet 2D-1	Emergency and evacuation lighting		
Worksheet 2E-1	Text book questions		
Worksheet 3A-1	Fire protection – residential fire and smoke alarms		
Worksheet 3B-1	Alternative supplies Summary / Revision		
Worksheet 3B-2	Text book questions		
Worksheet 3C-1	Installation of batteries		
Worksheet 4A-1	Lighting circuits – looping at the light/switch		
Worksheet 4B-1	Circuits for socket outlets		
Worksheet 4C-1	Final sub-circuits and segregation		
Activity 4D-1	Installation practice		

References

- Electrical Principals for Electrical Trades – Volumes 1 (6th ed.) Jenneson & Harper
- Electrical Wiring Practice – Volumes 1 & 2 (7th ed.) Pethebridge & Neeson
- AS/NZS 3000 (current edition)
- Code of Practice – Safe electrical work on low voltage electrical installations
- WA Electrical Requirements

Competency Standard Units

UEENEEG033A Solve problems in single and three phase low voltage electrical apparatus and circuits

Prerequisite Units

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

UEENEEE101A	Apply Occupational Health and Safety regulations, codes and practices in the workplace
UEENEEE102A	Fabricate, dismantle, assemble of electrotechnology components
UEENEEE104A	Solve problems in d.c circuits
UEENEEE105A	Fix and secure electrotechnology equipment
UEENEEE107A	Use drawings, diagrams, schedules, standards, codes and specifications
UEENEEG101A	Solve problems in electromagnetic devices and related circuits
UEENEEG102A	Solve problems in low voltage a.c. circuit
UEENEEG106A	Terminate cables, cords and accessories for low voltage circuits

ELEMENT	PERFORMANCE CRITERIA
1 Prepare to solve single and three phase low voltage electrical apparatus/ circuit problems.	1.1 OHS procedures for a given work area are identified, obtained and understood. 1.2 Established OHS risk control measures and procedures in preparation for the work are followed. 1.3 Safety hazards, which have not previously been identified, are noted and established risk control measures are implemented. 1.4 The nature of the apparatus/circuit(s) problem is obtained from documentation or from work supervisor to establish the scope of work to be undertaken. 1.5 Advice is sought from the work supervisor to ensure the work is coordinated effectively with others. 1.6 Sources of materials that may be required for the work are established in accordance with established procedures. 1.7 Tools, equipment and testing devices needed to carry out the work are obtained and checked for correct operation and safety.
2 Solve single and three phase low voltage electrical apparatus/circuit problems.	2.1 OHS risk control measures and procedures for carrying out the work are followed. 2.2 The need to test or measure live is determined in strict accordance with OHS requirements and when necessary conducted within established safety procedures. 2.3 Apparatus/circuits/plant is checked as being isolated where necessary in strict accordance OHS requirements and procedures. 2.4 Established methods are used to solve apparatus/circuit problems from measure and calculated values as they apply to single and three-phase low voltage apparatus/circuit.

ELEMENT	PERFORMANCE CRITERIA
	2.5 Established methods for dealing with unexpected situations are discussed with appropriate person or persons and documented.
	2.6 Unexpected situations are dealt with safely and with the approval of an authorised person.
	2.7 Problems are solved without damage to apparatus, circuits, the surrounding environment or services and using sustainable energy practices.
3 Complete work and document problem solving activities.	3.1 OHS work completion risk control measures and procedures are followed.
	3.2 Work site is cleaned and made safe in accordance with established procedures.
	3.3 Justification for solutions used to solve apparatus/circuit problems is documented.
	3.4 Work completion is documented and an appropriate person or persons notified in accordance with established procedures.

Required Skills and Knowledge This describes the essential skills and knowledge and their level, required for this unit.
KS01-EG033A Electrical apparatus and circuits

Evidence shall show an understanding of electrical apparatus and circuits to an extent indicated by the following aspects:

T1 Lighting circuits – looping at the light/switch encompassing:

the "loop at the light" method of wiring lighting circuits.

the "loop at the switch" method of wiring lighting circuits

wiring diagrams for the lighting circuit of an installation that incorporates one-way, two-way and two-way and intermediate switching of light points using the loop at the light/switch methods of TPS wiring.

TPS cabling requirement for the loop at the light/switch circuit.

installation methods of accessories and wiring for a lighting circuit incorporating one-way, two-way and two-way and intermediate switching of lighting points using the loop at the light/switch method of TPS wiring.

correct operation of the install circuits including testing for correct compliance with Australian Standards.

T2 Circuits for socket outlets encompassing:

the purpose of socket outlets.

requirements concerning the polarity of switched socket outlets.

correct cable size to supply 10 A, 15 A and 20 A socket outlets (single and three phase), for given installation conditions.

number of socket outlets connected to a 16 A and 20 A circuit breaker.

installation methods of a single phase socket outlet circuits.

correct operation of the installed circuits including testing (dead testing only) for correct compliance with Australian Standards.

T3 Final sub-circuits and segregation encompassing:

purpose of mixed circuits.

circuit loading for a mixed circuit.

purpose of segregation of circuits and the AS/NZS3000 requirements.

Installation methods a single phase mixed circuits.

correct operation of the installed circuits including testing for correct compliance with Australian Standards.

T4 Electrical heating control devices encompassing:

methods of manual heat control.

methods of automatic heat control.

types and application for common thermostats.

operation of common thermostats.

sensitivity and differential of thermostats.

testing of a thermostat (including differential and correct operation)

applications of simmerstats (infinite controls).

operation of a simmerstat.

electronic heat control (phase control and zero voltage switching).

T5 Fixed electrical heating appliances encompassing:

Terms: heat energy, temperature, specific heat capacity, thermal conductivity and thermal stability.

determining the heat energy in joules and kWh in a simple heating process.

methods of heat transfer.

Determining the heat energy input and output of a heating process.

connections to a two phase stove.

operation of reverse cycle air conditioning.

T6 Electrical water heater operation encompassing:

types of water heaters (instantaneous and storage) and their methods of control.

intrinsic safety (pressure relief and thermal cut-out).

testing of over temperature cut-out point of a thermostat.

switchboard requirements to supply a controlled load water heater.

internal circuit of a twin element water heater, and supply connections.

tariffs employed by local supply authorities.

solar heating system and its integration into an installation.

T7 Alternative supplies encompassing:

reasons for the installation of alternative supplies.

types of alternative supply systems.

characteristics and operation of UPSs.
Australian Standards and local requirements for safety services supply systems.

T8 Installation of batteries encompassing:
common types of primary cells and secondary batteries and typical applications.
terminal voltage of common primary cells and secondary cells.
correct storage, handling and disposal techniques for cells and batteries.
charge/discharge cycle for a secondary cell.
effect of internal resistance on a secondary cell.
state of charge of a secondary cell.
installation of batteries as per AS/NZS3011
commissioning procedures for various secondary batteries.
safe working procedures when working with secondary cells and batteries.

T9 Fire protection – residential fire and smoke alarms encompassing:
types of fire and smoke alarms.
regulations and standards requirements regarding residential fire and smoke alarms.
locations for residential fire and smoke alarms.
wiring methods for residential fire and smoke alarms.
operation of typical residential fire and smoke alarms

T10 Emergency and evacuation lighting and lighting control encompassing:
factors and requirements of emergency and evacuation lighting concerning illumination levels, luminaire positioning and operating period.
characteristics of maintained, non maintained and sustained emergency lighting systems.
arrangement of batteries in point and central bank emergency lighting supply systems.
lighting control methods

T11 Lighting concepts and incandescent lighting encompassing:
basic concepts of lighting.
terminology, principles and standards relevant to lighting (energy efficiency as per BCA new lamp types and permitted replacements and their efficacy)..
basic types of luminaries.
operation of an incandescent lamp.
types of incandescent lamps.
expected lamp life, colour rendering and efficacy for typical incandescent lamps.
lighting layout in terms of visual comfort and relevant Australian standards

T12 Fluorescent low intensity discharge lighting encompassing:
types of low intensity discharge lamps.
expected lamp life, colour rendering and efficacy for typical types of low intensity discharge lamps.
operation of low intensity discharge luminaires including their control equipment.
Australian Standard and local requirements for low intensity discharge lighting.
methods for satisfying Australian Standards and local supply authority requirements regarding low intensity discharge lighting.

T13 High intensity discharge lighting encompassing:
types of high intensity discharge lamps.
expected lamp life, colour rendering and efficacy for typical types of high intensity discharge lamps.
operation of high intensity discharge luminaires including their control equipment.
Australian Standard and local requirements for high intensity discharge lighting.
methods for satisfying Australian Standards and local supply authority requirements regarding high intensity discharge lighting.
LED lighting and its applications.
Neon, Argon and Xenon lighting and their applications.
comparison of incandescent, low intensity discharge, high intensity discharge, LED and other types of lighting

G033A Work Performance Tasks – (Q Tracker tasks):

UEENEEG033A – Solve problems in single and three phase low voltage electrical apparatus and circuits	
This unit shall be demonstrated in relation to any four types of problems for both single and three-phase apparatus and circuits and three types of circuit/equipment as listed below.	
Type of problems	• Determining the operating parameters of existing apparatus/circuit • Altering an existing apparatus/circuit to comply with specified operating parameters • Developing apparatus/circuits to comply with a specified function and operating parameters Note: Operating parameters include voltage, current, efficiency, power, energy and power factor • Determining the cause of low efficiency in an existing apparatus/circuit. • Determining conditions causing an existing apparatus/circuit to be unsafe. Note: Examples of unsafe circuits includes electric shock hazard from indirect contract with conductive parts, insufficiently low impedance of a fault current path and inadequate fault protection
Types of circuits/equipment	• Lighting circuits • Power circuits • Rotating machines • Electrical heating • Lighting

Workplace Rules:

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

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

UEENEEG033A - Solve problems in single and three phase low voltage electrical apparatus and circuits

Learning and Assessment Plan

Name of Lecturer: ____

Contact Details: ____

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

Using:

Session	Nominal Duration	Program of Work (Topics to be covered)	Primary Reference
1	1 hour	Introduction to UEENEEG033A Recognition of Prior Learning	
2	4 hours	Fixed electrical heating appliances	Resource Book
3	4 hours	Electrical heating control devices	Resource Book
4	4 hours	Electrical water heater operation	Resource Book
5	3 hours	Theory and practical assessment	Resource Book
6	3 hours	Lighting concepts and incandescent lighting	Resource Book
7	4 hours	Fluorescent low intensity discharge lighting	Resource Book
8	5 hours	High intensity discharge lighting	Resource Book
9	2 hours	Emergency and evacuation lighting and lighting	Resource Book
10	3 hours	Theory and practical assessment	Resource Book
11	2 hours	Fire protection – residential fire and smoke alarms	Resource Book
12	1 hour	Alternative supplies Summary / Revision	Resource Book
13	2 hours	Installation of batteries	Resource Book
14	1 hour	Theory Assessment	Resource Book
15	1 hour	Lighting circuits – looping at the light/switch	Resource Book
16	1 hour	Circuits for socket outlets	Resource Book
17	1 hour	Final sub-circuits and segregation	Resource Book
18	12 hours	Practical Installation practice	Resource Book

I acknowledge that I have received and read this Delivery and Assessment Plan Student Name:____________________ Signature: __________________ Date: _________		
Lecturer Name	Lecturer Signature	Date

Assessment Strategy

Conditions of Assessment:

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

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

Assessment Methods:

Resource Book - The satisfactory completion of all worksheets and practical activities is required.

Written Theory Assessment – based on the **REQUIRED SKILLS AND KNOWLEDGE**. You must achieve a mark of 75% or more in this assessment.

Observed Practical Assessment – based on the Elements and Performance Criteria of this Competency Unit UEENEEG033A. You must achieve a mark of 100% in this assessment.

On-Job-Training:

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

Sufficiency of Evidence:

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

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

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

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Danger Tag Procedure

Use of Danger Tags

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

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

Image - Polytechnic West 2014

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

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

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

Points to Watch

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

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

Fasten the danger tag securely.

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

Failure to follow Danger Tag Procedures when working on practical activities and practical assessments will result in a **Not yet competent** comment recorded for this Unit of Competency – UEENEEG033A

Student's Signature __________________________ Date: __________________

LABORATORY and WORKSHOP SAFETY INSTRUCTIONS

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

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

Student's Signature _________________________ Date: _________________

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 1 Part A**	**Revised 07/2014 UEENEEG033A**

Fixed electrical heating appliances:

Topic 5	**Required skills and knowledge:**
	• Terms: heat energy, temperature, specific heat capacity, thermal conductivity and thermal stability. • determining the heat energy in joules and kWh in a simple heating process. • methods of heat transfer. • Determining the heat energy input and output of a heating process. • connections to a two phase stove. • operation of reverse cycle air conditioning.

Student Activity	**Done**	
Read Section **6.1 and 6.2 Appliances and Heating methods and control in** Electrical Wiring Practice (7th ed.) Vol.2 Page 159 to 161		
Read Section **6.4 Heating systems and 6.5 Process heating in** Electrical Wiring Practice (7th ed.) Vol.2 Page 173 to 183.		
Read AS/NZS3000:2018 Section 4.7 Cooking appliances		

Concepts of Heat Energy

Energy
When a body is capable of doing work, it is said to possess energy. The amount of work a body can do is a direct measure of its energy, or the amount of energy expended is measured by work done by the body. The unit of energy is therefore the same as the unit of work.

Example: - A weight of 50 Newtons raised 5 metres vertically has 250 Joules of potential energy, which it can give in falling. In being brought to a stop, it will expend 250 Joules of kinetic energy altogether.
It is therefore possible to obtain work by releasing stored energy. This leads to the conservation of energy principle.

Heat is a form of energy and temperature is a measure of the level of heat in a body.

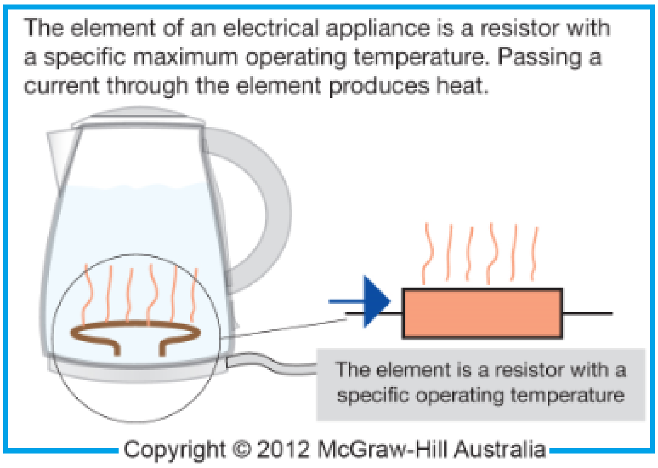
Conservation of energy
Energy can neither be created nor destroyed when energy appears in one form it disappears in another form by the same amount.

Conversion of energy from one form to another is a common aim in engineering. An electric motor, for example, is made specifically to convert electrical energy into mechanical energy. Practical methods of energy conversion are not, ideal because not all the energy taken from the original source is converted to the form required for use. Some of the energy is converted into forms that cannot be used and as such are termed losses. Some of the energy taken by the motor in our example is converted into heat energy in the windings, the steel and the bearings.

Electrical Energy
Energy is the product of power and time. An electrical heating appliance converts electrical energy into heat energy. The energy expended in Joules is the power in Watts multiplied by the time in seconds (**1 Joule = 1 Watt per second**). Since the Joule is a small unit it is more common to express electrical energy as a product of power in kilowatts and time in hours, i.e. kilowatt hours (kWh). 3,600,000 Joules give 1 kWh.

One kWh is a unit of electricity. Depending on the amount of energy consumed and the application, a tariff is determined. Cheaper tariffs apply for bulk purchases of electrical energy and for off peak consumers where the usage is controlled by time clocks, day/night switches, booster relays or dual tariff electronic meters.

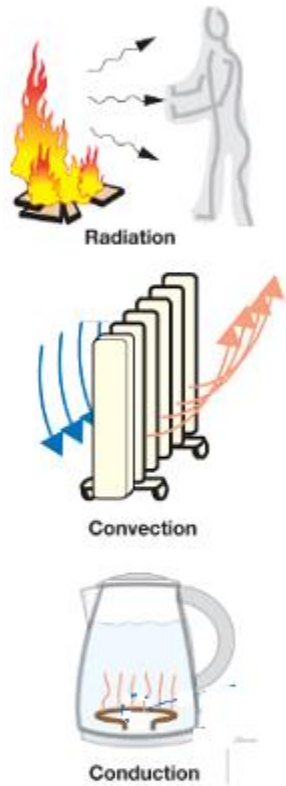
Heat energy
Current passing through a resistive element converts electrical energy into heat energy. Heat energy travels from a point of higher temperature to a point of lower temperature.



Heat transfer
When heat travels from a point of higher temperature to a point of lower temperature, the rate of transfer is dependent on the temperature difference between the mediums transferring the energy via conduction, convection or radiation.

Heat energy is transferred in three ways:-

Radiation
Radiation is the transmission of heat energy away from an object in a way that involves no material means of transfer. Heat is transferred as infra-red electromagnetic radiation waves. As its transmission is in straight lines only, it may be directed or focused by suitable reflectors. A bright or polished surface reflects, and does not absorb most of the radiant energy that falls on it. A polished surface is also a poor heat radiator. A matt black surface is the best absorber and radiator of heat, and the quantity of heat radiated rises as the temperature increases. Radiant heat is transmitted from a hotter to a colder body without appreciably heating the air through which it passes.



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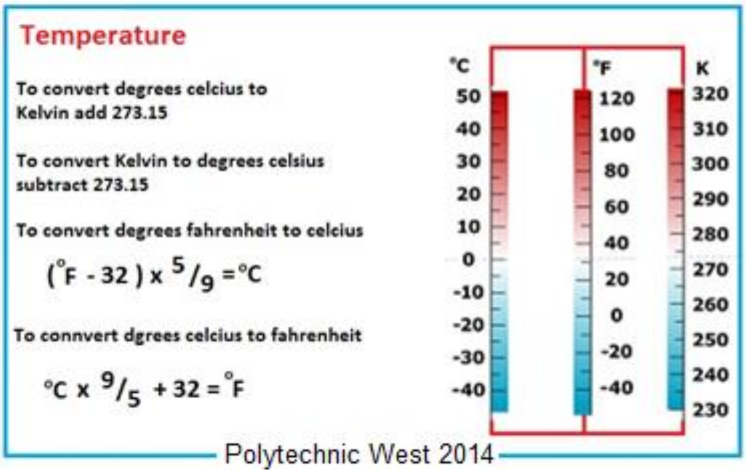
Convection
Convection involves the transfer of heat by the circulation of a fluid, liquid or gas where circulating currents can be formed. If the transfer is caused by the natural motion of the medium due to different densities it is called natural convection. If the energy transfer is due to movement caused by a fan or pump it is called forced convection.

Conduction
Conduction is the transfer of heat energy directly from one body to another. When the body of a substance is not uniform heat is transferred to minimise the temperature difference by conduction.

Effects of heat
Heating a substance can:

- increase the temperature of the substance
- cause a change in the substance state, i.e. solid, liquid, gas

- expand in volume or length
- emit light
- emit electrons
- change resistance
- generate an emf



Temperature
Temperature is the measure of the degree of hotness or coldness of a body. When heat is applied to a body the temperature rises and if taken away the temperature falls. The temperature change indicates the direction of heat exchange between bodies.

The practical SI unit of temperature is the degree **Celsius**. At atmospheric pressure the freezing point of water is 0 degrees Celsius and boiling point 100 degrees Celsius.

Water freezes at 32 degrees **Fahrenheit** and boils at 212 degrees Fahrenheit.

Kelvin is a thermometric scale starting at absolute zero. Absolute zero is minus 273.15 degrees Celsius.

Thermal efficiency can be improved by reducing the amount of heat that escapes to the atmosphere. This can be done by covering the outer surfaces of the hot water storage tank (and pipes) with a thermal insulator such as fibreglass.
This process is known as "lagging" the tank or pipes.

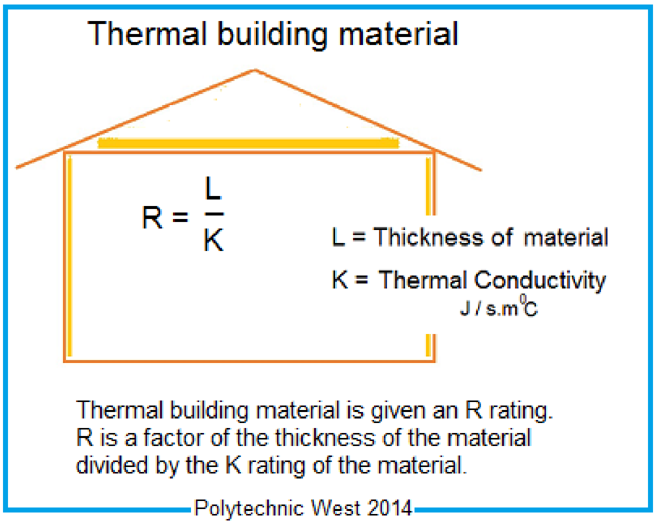
Specific heat
Specific heat capacity is the quantity of heat energy required to raise the temperature of a mass of one kilogram through one degree Kelvin.
When identical masses of different materials are heated by equal quantities of heat energy they will all show different temperature increases. This is the specific heat capacity of the material being heated. The following are approximate examples since the values of specific heat capacity vary with temperature.

Specific heat capacities: -	Water	4180 Joules/kg.K
	Copper	390 Joules/kg.K
	Aluminium	900 Joules/kg.K

Thermal conductivity

The rate of heat conduction through a material is measured in Watts and depends upon:

1. Temperature difference across the material
2. Cross sectional area of the transfer path
3. Length of transfer path
4. Type of material



The unit quantity of heat energy is the joule(J)
1 joule is 1 watt for one second(1J = 1Ws)

To determine the amount of heat energy required to raise the temperature for any material use:-

$$Q = mc\,(t_2 - t_1)$$

Where **Q** is quantity of heat in Joules
c is the specific heat capacity
m is mass in kg
t_1 is initial temperature
t_2 is final temperature

Note: When a problem involves a body containing some other material being heated each material must have their heat energy calculated separately. The sum of all bodies being heated is the total energy required.

Example 1 Calculate the heat energy required to raise the temperature of 100 grams of water from 20 degrees Celsius to 100 degrees Celsius

$Q = mc\,(t_2-t_1)$
$= 0.1 \times 4180\,(100-20)$
$= 33440$ Joules

Example 2 Calculate the time taken for a full 2kW, 1.7 litre electric kettle to raise the water temperature from 18 degrees Celsius to boiling point.

$Q = mc\,(t_2-t_1)$
$= 1.7 \times 4180\,(100-18)$
$= 582692$ Joules

Joules/3600000 = kWh

582692/3600000 = 0.16186 kWh

kWh/kW = h
0.16186 / 2 = 0.08093 hours

Hours x 60 = minutes
0.08093 x 60 = 4.856 minutes

Radiant heater

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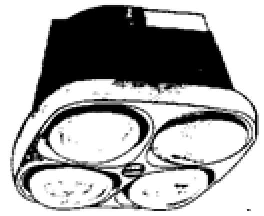
Radiators
Current flowing through a resistive nichrome alloy element causes a change in the temperature of the radiator bar element. The element temperature of about 900 degrees Celsius (dull red) radiates heat to produce a change in temperature of objects in front of the radiator, or as directed by the reflector. Other types include infra-red and metal sheathed elements.

Strip heaters are generally of an infra-red type having the element enclosed in a silica tube which is mounted above head high on a wall. It is usually controlled by a pull or permanently wired switch.

Low temperature heaters
These include panel heaters, fan heaters, thermal storage heaters, under floor heating and ceiling radiant heating.

Panel heaters
Heating panels attached to skirting boards deliver heat by natural convection or radiation. Operating between 60 and 70 degrees Celsius the thermostatically controlled foil element oil filled units are effective for enclosed spaces.



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Fan heaters
By increasing air circulation using a motor driven fan (forced convection) the heating element can deliver a switched, variable, fast, even change in temperature. The blockage of air flow or a change in fan speed should cause a thermal protection device to operate. Other applications of this principle include hair dryers, hot air paint strippers and conduit bending units.

Infra-red
Halogen infra-red lamps are widely used for localised heating. Typical applications include heat ray lamps for muscle injury repair, paint drying as used in the automotive industry and bathroom heaters. The Ruby fronted lamps reduces visible light are used for non-domestic applications such as animal rearing.

Space heating

Halogen infra-red space heating, giving up to 86% radiant heat with very little transmission loss through air, is ideal for large areas having intermittent use since it has instant heat and is easily controlled using a normal resistive load dimmer or by digital control.

Thermal storage units

A typical unit consists of externally insulated bricks surrounding a controlled heating element. Heat is extracted from the unit heat using fans which are controlled by a room thermostat. The heat bank is designed to draw energy from the supply only during off peak hours, while providing normal space heating at any time of the day or night.

Floor heating

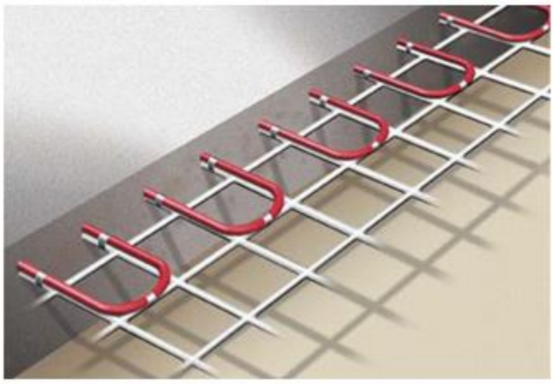
There are two types available:-

1. Under carpet
2. In concrete

Image © Polytechnic West 2014

Under carpet

Heating elements are layered between sheets of aluminium installed beneath the carpet. It is protected by hardboard if installed beneath linoleum. On floor heating of this type gives a quick temperature rise but does not have the heat storage capacity of in concrete heating.



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In concrete

Electric storage floor heating utilises heating cables installed in the concrete slab or tile bed prior to a floor being finished, or the floor surface or coverings being placed. It is particularly efficient for multi-storey buildings. Due to a floors thermal mass storage capacity it has the advantage of being cost efficient as it is operated at off peak tariff rates. Thermostats controlling air temperature should be set to 16 degrees Celsius and safety over temperature thermostats to 26 degrees.

It is far better to lay the element under the slab to prevent breakage of the element cables due to movement within the concrete. It also makes better use of the rising heat off the element. This method however is not commonly applied in Australia but is widely used in Europe.

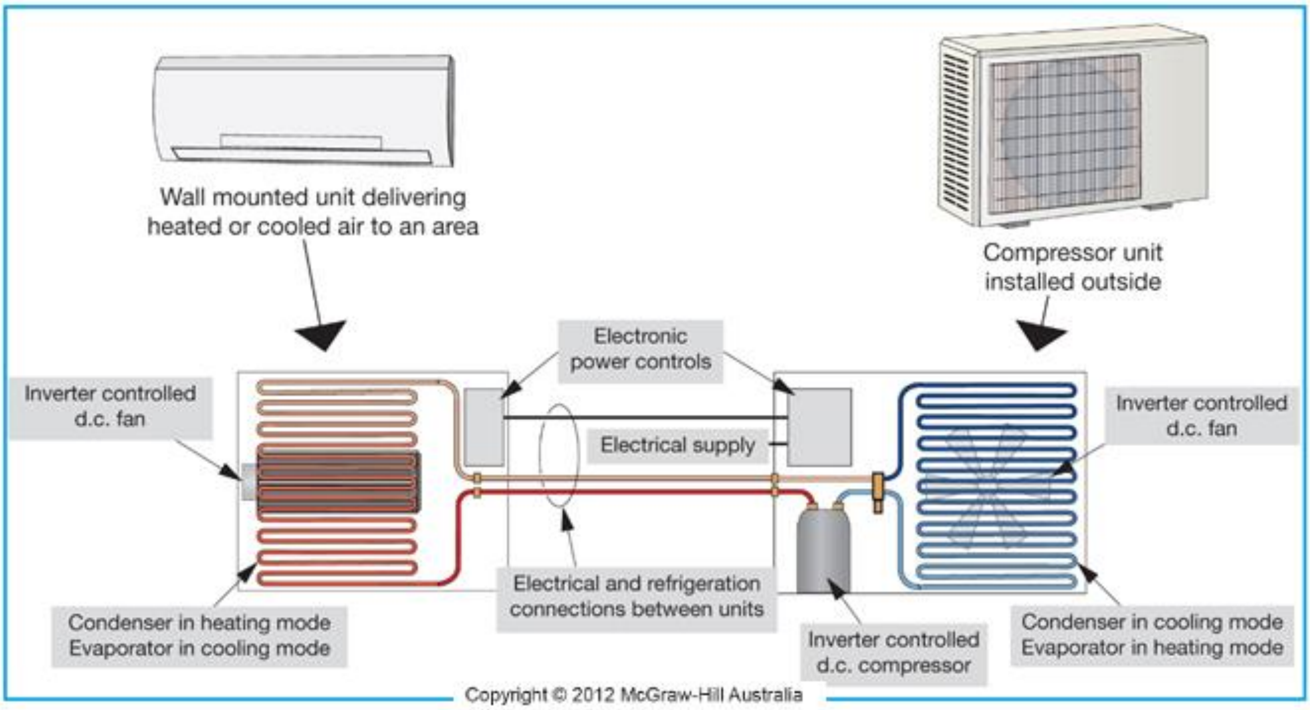
Ceiling radiant heating

A typical heated ceiling is installed using low temperature flat elements which are sealed in plastic laminate and installed on the ceiling under insulation in the form of a pad. MIMS heating cable can be used also for ceiling and wall heating. Heating a ceiling or wall using this method is relatively inexpensive to install, but is not as widely used as under carpet or in concrete floor heating systems. Very little thermal storage capacity is available in a ceiling making this system unsuitable for off peak tariff control.

Image © Polytechnic West 2014

Under floor heating - refer to Electrical wiring practice Volume 2 page 180

Refrigerated air conditioning
A refrigerated air conditioning unit, when on its cooling cycle pumps unwanted heat out of an area. The cycle can be reversed to heat the room. Heating or cooling is provided by using a refrigeration system to exchange heat between the internal and external air. Reverse cycle air conditioning is extremely efficient compared to other forms of space heating.



Two principles of refrigeration are at play here:
Liquids absorb heat when changed from liquid to gas
Gases give off heat when changed from gas to liquid.

Refrigerated air conditioner systems use a continuous cycle of compression, condensation, expansion, and evaporation in a closed circuit.
The refrigerant comes into the compressor as a low-pressure gas, it is compressed and then flows out of the compressor at a high-pressure.

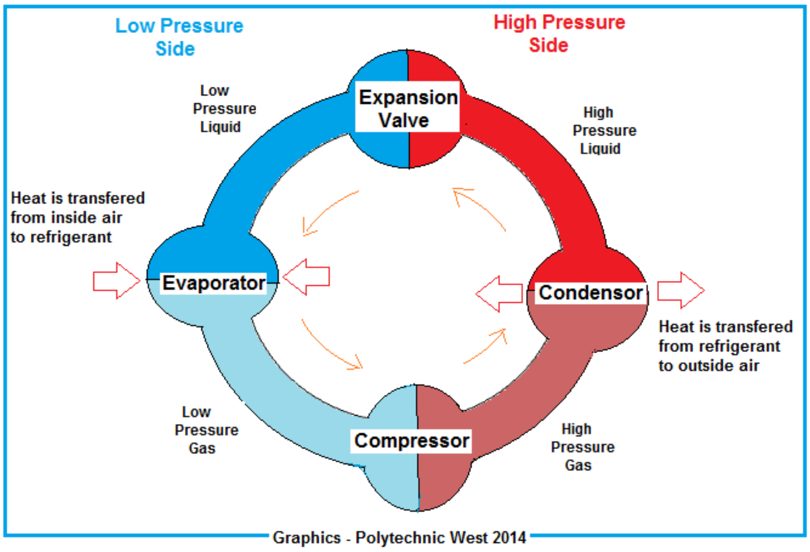
The gas flows to the condenser where it condenses to a liquid and transfers its heat to the outside air.

The liquid then flows to the expansion valve under high pressure.

This valve restricts the flow of the fluid, and lowers its pressure as it leaves.

The low-pressure liquid then flows to the evaporator, where heat from the inside air is absorbed and changes it from a liquid to a gas.

As a hot low-pressure gas, the refrigerant moves to the compressor where the entire cycle is repeated.

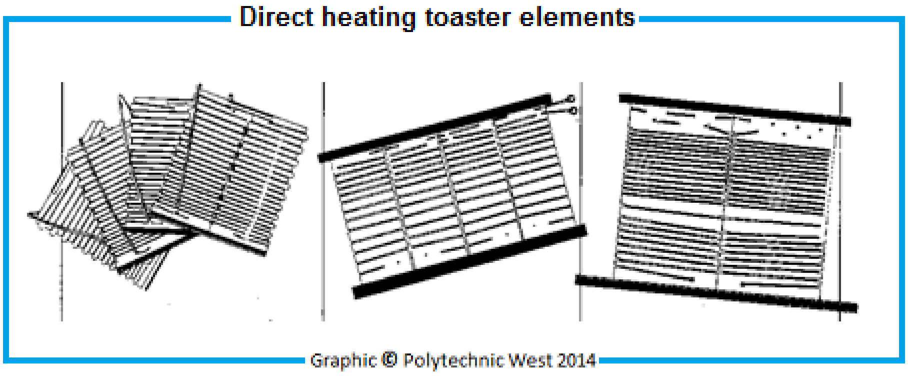


Cooking

Types of electric cooking methods include:

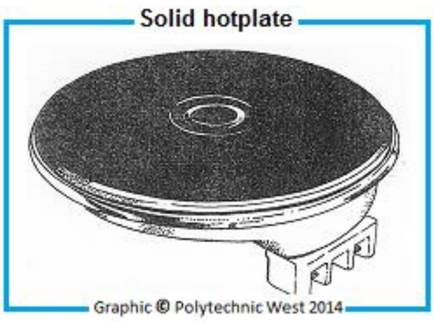
1. Resistance elements
2. Induction heating
3. Microwave

Resistance heating
There are a variety of resistance heating element styles available. These range from the standard wire wound resistance elements (eg direct heating toaster elements)and those which rely on conduction between the contact of the element and the vessel being heated to newer styles under ceramic glass tops.

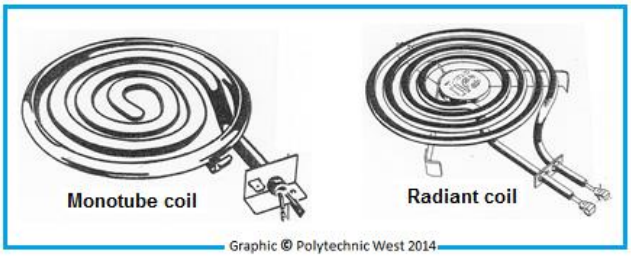


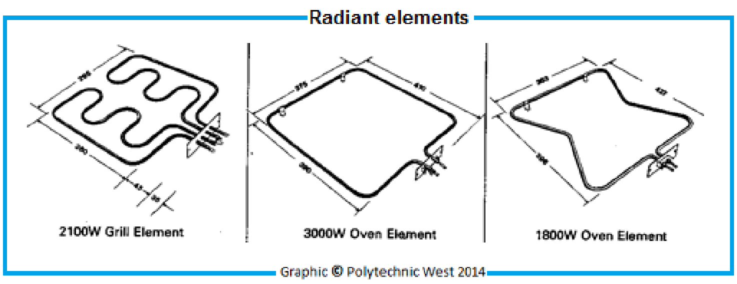
The older solid construction, monotube coil element and radiant coil element style units have relatively low heat transfer efficiency.

Solid hotplates are variable control hotplates with excellent energy efficiency and superior simmering performance though slower to heat up and cool down.

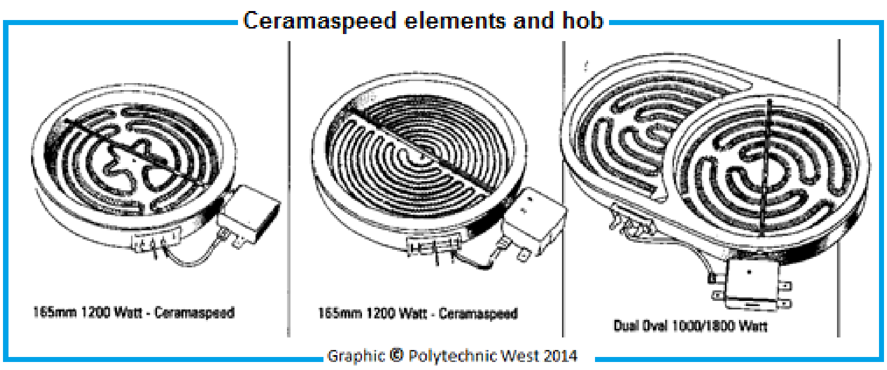


Monotube and radiant coil elements have quick response and lift/swivel up to allow for cleaning of the spill bowls placed beneath them.





Wire wound cerama-speed elements inserted in hobs directly under ceramic top heat up within 3 to 6 seconds and are extremely efficient compared to the older style coil elements. The open wound element is clearly visible when energised.



A modern form of resistance heating is halogen cook tops. Infrared halogen elements are long life tubular quartz halogen lamps which may be mounted under a shatter proof glass hob, in grillers, ovens or food warmers.

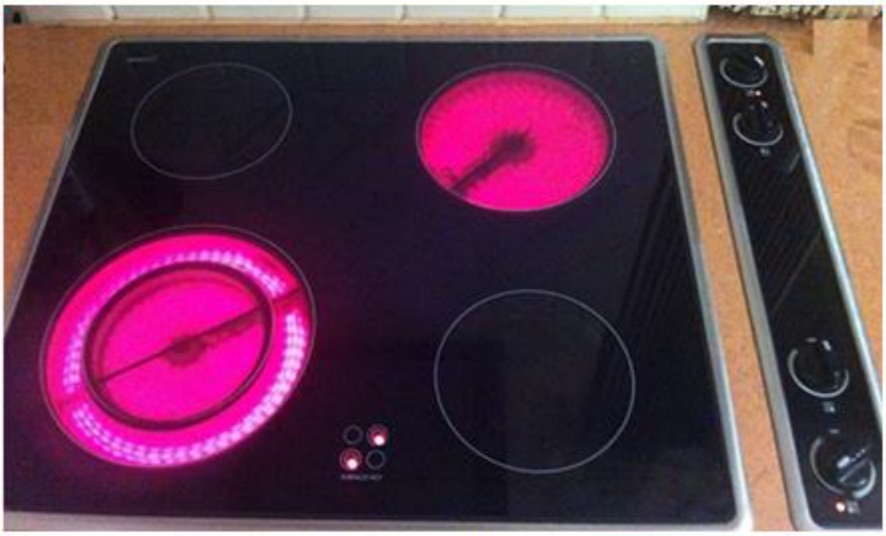


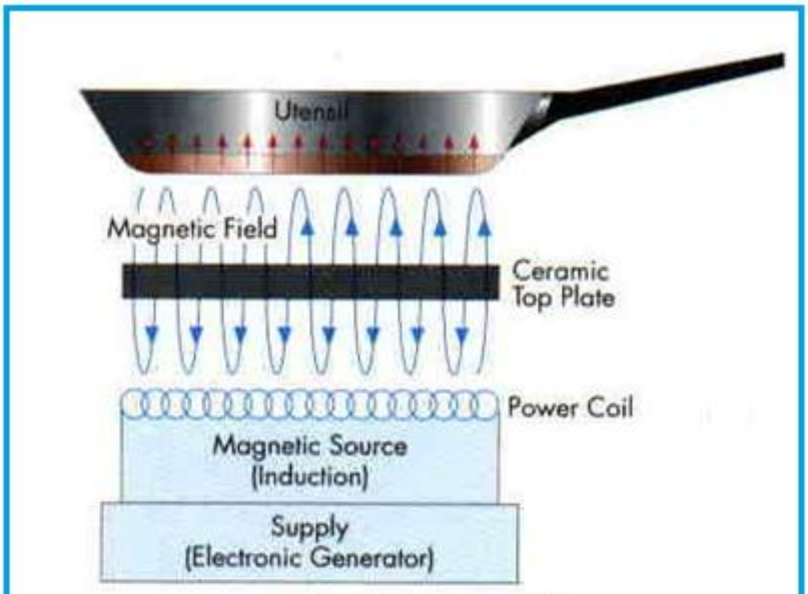
Image © Polytechnic West 2014

Quartz halogen cooking elements

When operating they produce both light and heat The hob containing the lamps are covered with a red glass to reduce visible white light and enhance the infra-red spectrum to aid heating. The tungsten filament in a halogen lamp operates at around 2750 degrees Celsius. At this temperature the halogen gas combines with tungsten as it evaporates away from the element. The combined mixture moves toward the cooler outer quartz envelop then reconstitutes back into its original components, redepositing tungsten on the filament as the gas swirls within the tube. Typically tubes of 500W, 800W, 1000W and 1200W are available for cook-tops.
Tube energy is regulated by pulsing the supply using an electronic controller. Radiated heat used in this manner is rapidly turned on and off, and is extremely efficient compared to other heating methods. The main disadvantage is cost which is about 40% dearer than conventional resistance heating cook-tops.
All ceramic glass cook-tops incorporate a temperature sensitive indicator to show that the cook-top is hot even though the energy source is turned off.

Induction heating

Using this method the vessel being heated must be of heavy metal structure. The saucepan is heated by eddy currents created in the base of the saucepan by an induction coil. The advantage of induction heating is that the

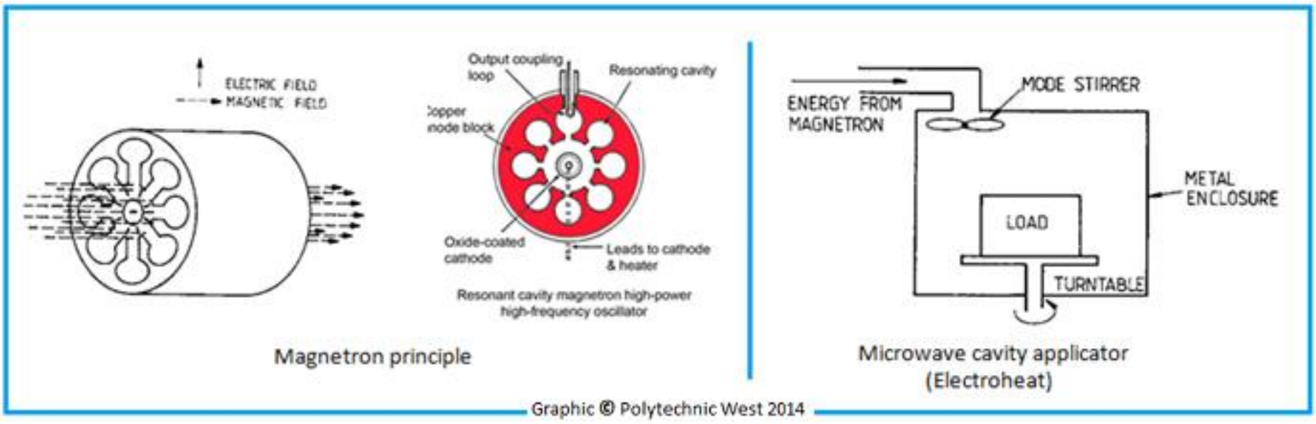


Graphic © Polytechnic West 2014

ceramic glass cooking surface does not get hot. If left turned on it resumes heating whenever a steel or cast object is over the appropriate area. Induction heating is relatively expensive being more than twice the cost of standard resistance element cook-tops. Using induction heating it takes about 3 minutes to boil a litre of water compared to about 7 minutes using a microwave oven.
Energy consumption is proportional to the size of the cooking vessel, resulting in substantial energy savings of 20% to 50% compared to a standard hob.
All ceramic glass cook-tops incorporate a temperature sensitive indicator to show that the cook-top is hot even though the energy source is turned off. In the case of induction heaters an indicator is used to show that the unit is on stand-by and ready for use.

Note. Materials to be heated by induction must be electrical conductors.

Microwave heating
A microwave oven uses electromagnetic energy at a frequency of 2.4 GHz generated by a magnetron tube. Unlike conventional cooking the microwaves radiate through the oven and penetrate any food within the oven. The food absorbs the energy from the waves that rapidly heat the food.



Magnetron principle
Microwave cavity applicator (Electroheat)
Graphic © Polytechnic West 2014

Switching devices for cooking appliances

Irrespective of the heating method domestic cooking appliances may be a free standing combination oven/hotplate unit, or an oven with separate hotplate unit.

The free standing combination oven/hotplate unit is connected to the supply protective device via a permanent connection or plug in connection.

AS/NZS3000 Clause 4.7.1 requires s circuit for a fixed cooking appliance with an open electric cooking surface have an accessible functional isolating switch, operating in all active conductors, is located in a visible and readily accessible position within 2m of the appliance in a position that the user does not have to reach across the open cooking surface.

A separate oven and hotplate unit is normally supplied from a common protective device.

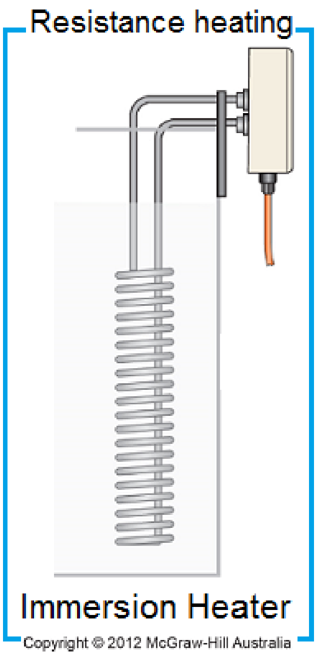
The extension connection between the range and hotplates is made using a suitably located junction box or termination point.

Both sections are considered as being the one unit in a maximum demand calculation when they are supplied from the one protective device.

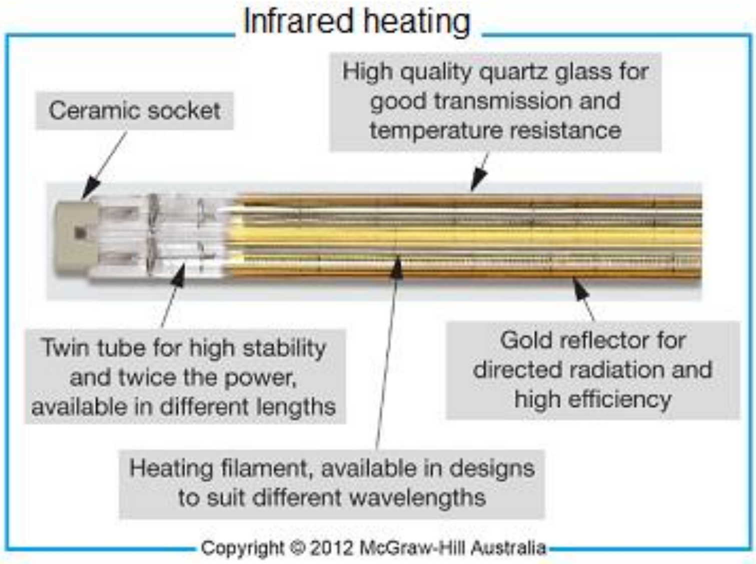
Process Heating

There are various types of heating process used in industry.
Some examples are:

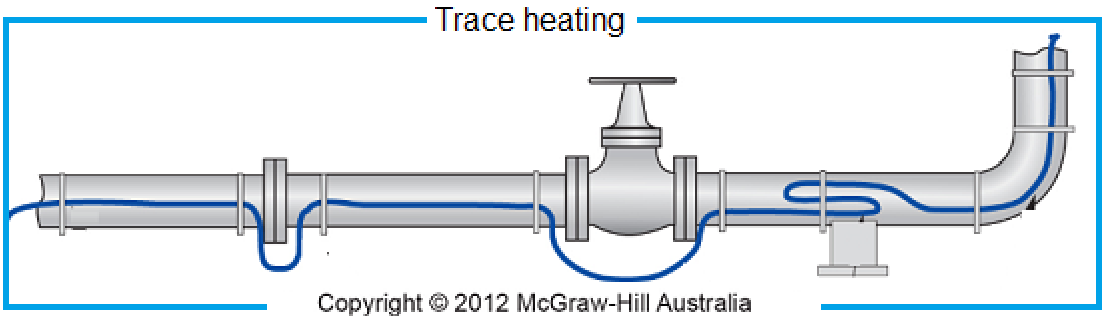
Resistance heating uses an element to heat the material.



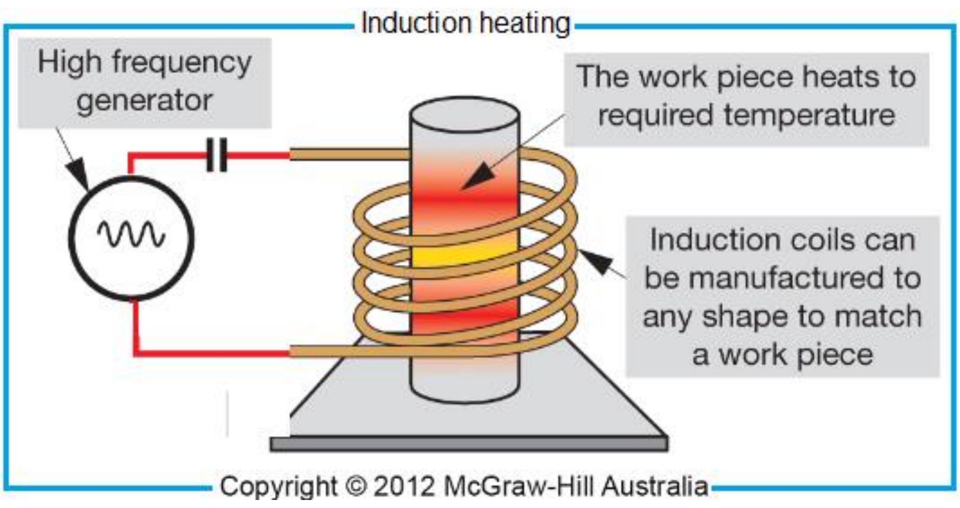
Infrared radiation is produced from a quartz tungsten lamp and used in many industries including textile, manufacturing, metal finishing and food processing.



Trace heating uses specially designed cables and tapes that attached to drums, pipes valves and vessels to heat the material like grease or oil to enable it to flow at the required rate.

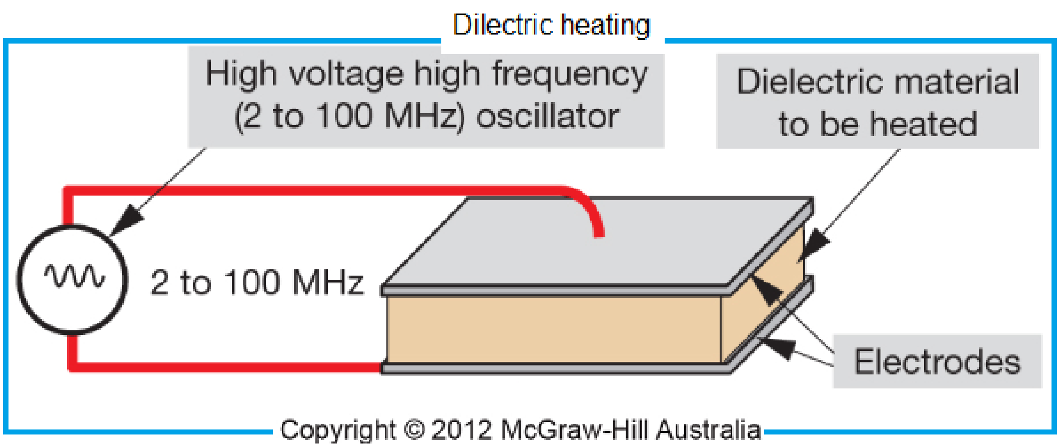


Induction heating is used for ferrous material. It works on the principle of induced eddy currents to heat the material.



For non-conductive material dielectric heating is used. The material to be heated is clamped between suitable plates to form the dielectric of a capacitor on high frequency AC . The main advantage of this process is that is quickly produces a uniform heat through the material.

Microwave heating is a form of dielectric heating but at much higher frequency usually over 2 GHz.



Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Work Sheet 1A -1**	**Revised 07/2014 UEENEEG033A**

1. Explain the difference between heat and temperature.

2 State the three methods by which heat can be transferred from one body or substance to another.

3. Define the term Specific Heat Capacity. What is the specific heat capacity of water?

4. What is the symbol for the basic unit of heat energy?

5. What is the basic SI unit for the LEVEL of heat?

6. What is the basic SI unit for the QUANTITY of heat?

7. Convert the following temperatures:

   68 ^{0}F to ^{0}C
   25 ^{0}C to K
   100 ^{0}C to ^{0}F

8. Define the term thermal conductivity.

9. List three factors which influence the thermal conductivity of a substance.

10. How is the thermal efficiency of a hot water system improved?

11. Describe the principle of operation of a reverse cycle air conditioner.

12. Give one practical example of a piece of equipment that uses the principle of convection in relation to heat developed.

13. Calculate the heat energy required to raise the temperature of 2000 g (2L) of water from 15 ^{0}C to 100 ^{0}C (Boiling).

14. Calculate the time taken for a 1.44kW, 2 litre electric kettle to raise the water temperature from 15 ^{0}C to boiling point.

15. What does the R rating and insulation material represent?

16. Name the four factors that affect the rate at which thermal conductivity occurs.

17. Name two types of electric cooking methods.

18. Within what distance does an isolating switch need to be installed for a cooking appliance with an open cooking surface? What is the AS/NZS Clause relating to this?

19. Describe the process for how an induction stove top element heats a frying pan.

20 Briefly describe the operation of a “di-electric” heating process.

21 List the main advantage of the di-electric heating process.

22 What type of material is the di-electric heating process designed to heat?

23 Briefly describe the operation of an “Induction” heating process.

24 List the main application of the Induction heating process.

25 What type of materials is the induction heating process designed to heat?

26 Name three types of cable used to heat floors.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 1 Part B**	**Revised 07/2014 UEENEEG033A**

Electrical heating control devices:

Topic 4	**Required skills and knowledge:**
	• methods of manual heat control. • methods of automatic heat control. • types and application for common thermostats. • operation of common thermostats. • sensitivity and differential of thermostats. • testing of a thermostat (including differential and correct operation) • applications of simmerstats (infinite controls). • operation of a simmerstats. • electronic heat control (phase control and zero voltage switching).

Student Activity	**Done**	
Read **Section 6.2 Heating methods and control in** Electrical Wiring Practice (7th ed.) Vol.2 Pages 161 to 165		
Read AS/NZS3000:2007 Section 4.8 Appliances producing hot water or steam		
Read **Thyristor phase control:** Electrical Principles for the Electrical Trade (6th ed.) Vol.2 Page 220		
Read **Zero voltage switching:** Electrical Principles for the Electrical Trade (6th ed.) Vol.2 Pages 228 - 230		

Electrical heating control devices

Manual Control

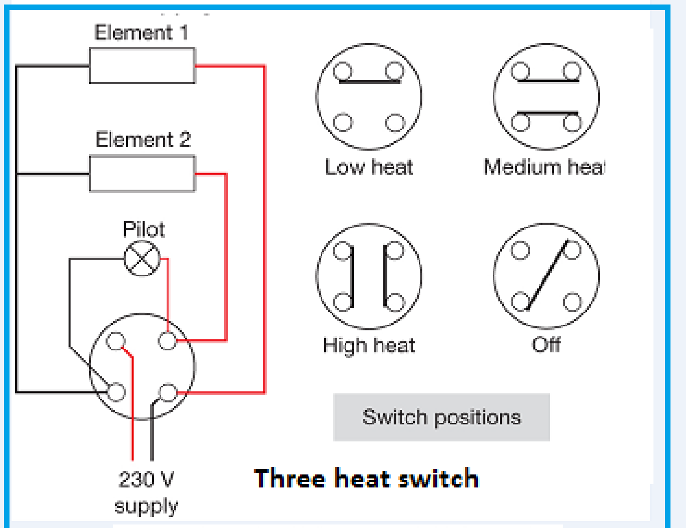
On/Off

The simplest form of control is by an on/off switch directly associated with the supply to the heating device. On/off controls are sometimes termed stepped controls. As they are manually set, control relies heavily on the judgement of the operator. Manual controls are relatively simple and inexpensive. Some heating devices (such as bar radiators) may have more than one on/off switch. Each switch controls the supply to a different element to give selection of the amount of energy being used.

A Three heat switch provides an on-off control statement.

Three Heat switching

Two identical elements may be switched to change their connection configuration using a special switch mechanism. (This method of switching is no longer commonly used and has been superseded by other forms of temperature control).

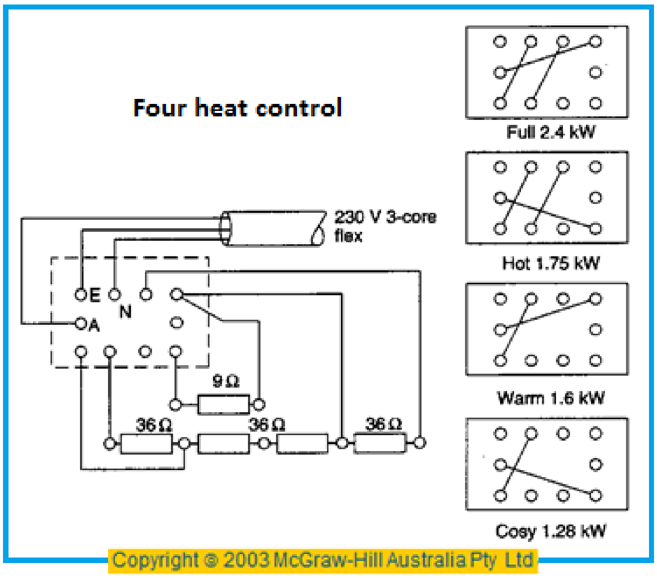


Low: two elements are connected in series to the supply

Medium: only one element is connected to the supply

High: Two elements are parallel connected to the supply

Double pole three heat switches are required for portable heaters.
Three heat switching is virtually obsolete since it has been largely replaced by thermostat or simmerstat controls.
The main advantage is that a double pole switch isolates neutral as well as active to prevent an active being at element terminals if incorrectly terminated at source.



A three phase water heater having twin heat elements operates in a similar manner to three heat switches. When low is selected the full resistance of the star connected elements is used. In high, a new star point is formed at a tapped portion of the element giving reduced resistance and a resultant higher current.

(c) Four Heat Control

Four heat switching works on the principle of combining elements in series/parallel combinations to give 1.28kW, 1.6kW, 1.75kW and 2.4kW ratings from a standard 240V, 10A supply.

Automatic Control

Thermostats

Thermostats control the temperature environment between an upper and lower limit. This difference is known as the differential. Therefore an oven can be maintained to a set temperature.

The ability to respond to a change in temperature is known as the sensitivity of the device. Thermostats attempt to maintain the temperature between the limits by the device automatically switching the element off when the temperature is at the upper limit and on when at or below the lower limit.

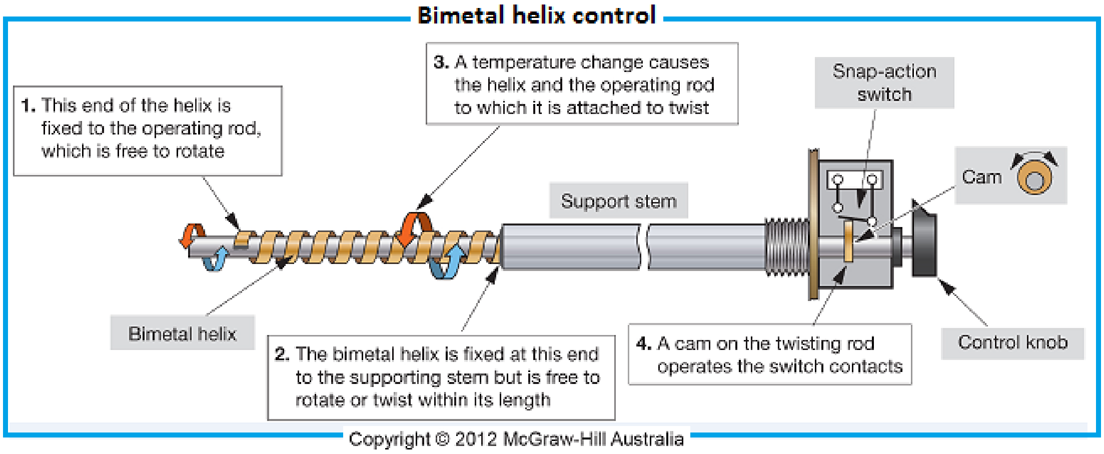
There is a link between the temperature being sensed and the control of the heating device when using a thermostat. They provide regulated, negative feedback control.

There are three main types of thermostats:-

1. Bi-metal
2. Expanding tube
3. Vapour pressure

Bi-metal

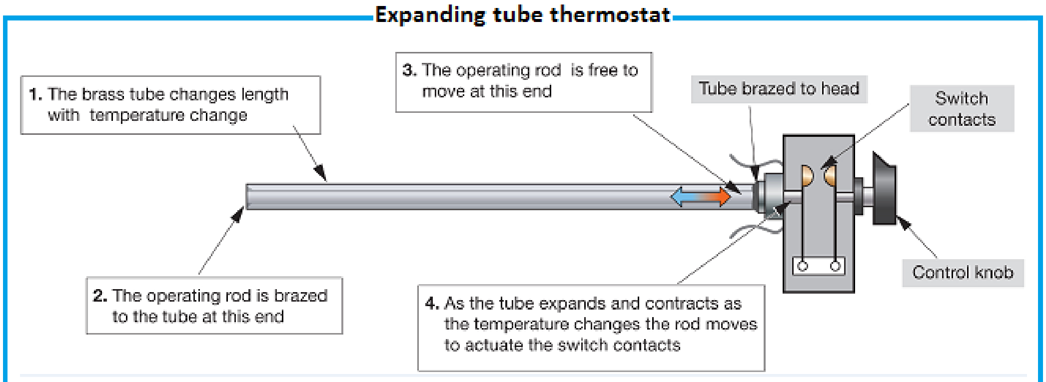
The bi-metal helix is fixed at one end to the supporting stem but is free to rotate or twist within its length. The other end of the helix is fixed to the operating rod, which is also free to rotate. A temperature change causes the helix and the attached rod to rotate, thus opening or closing a set of contacts. The rod is made of invar (an alloy having negligible coefficient of expansion).
It is used in appliances and room heating operating with a differential 3 degrees Celsius.



Expanding tube - Commonly used in Water heaters

The length of a brass tube changes with variations in temperature. The differential expansion between the inner rod and the outer tube which are mechanically linked at the bottom of the tube results in a fast response to changes in temperature. It can maintain a differential of 1 degree Celsius between the range of 20 to 300 degrees.

Expanding tube thermostat



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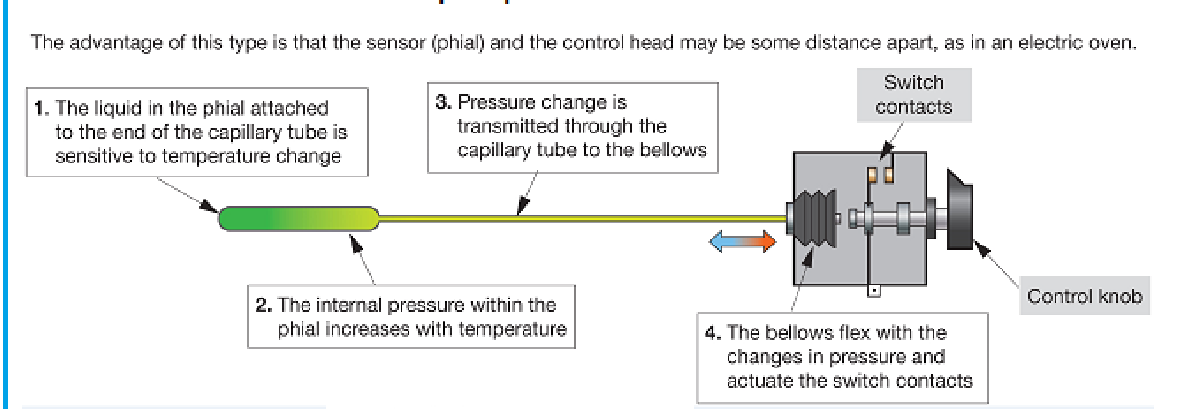
Vapour pressure
Vapour filled thermostats are relatively unaffected by ambient temperature variations and operate within a 3 degree Celsius differential. They are available within a temperature range of typically-40 to 600 degrees Celsius. They are commonly used in electric ovens and refrigeration equipment.

Vapour pressure thermostat



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Fixed temperature contact thermostats open the bi-metal contacts at pre-set temperatures. These are commonly used in single phase motors to monitor then switch off the motor if the windings over heat due to overload conditions. Some models can be reset.
These can be seen in water heaters when the water temperature increases beyond the required temperature.

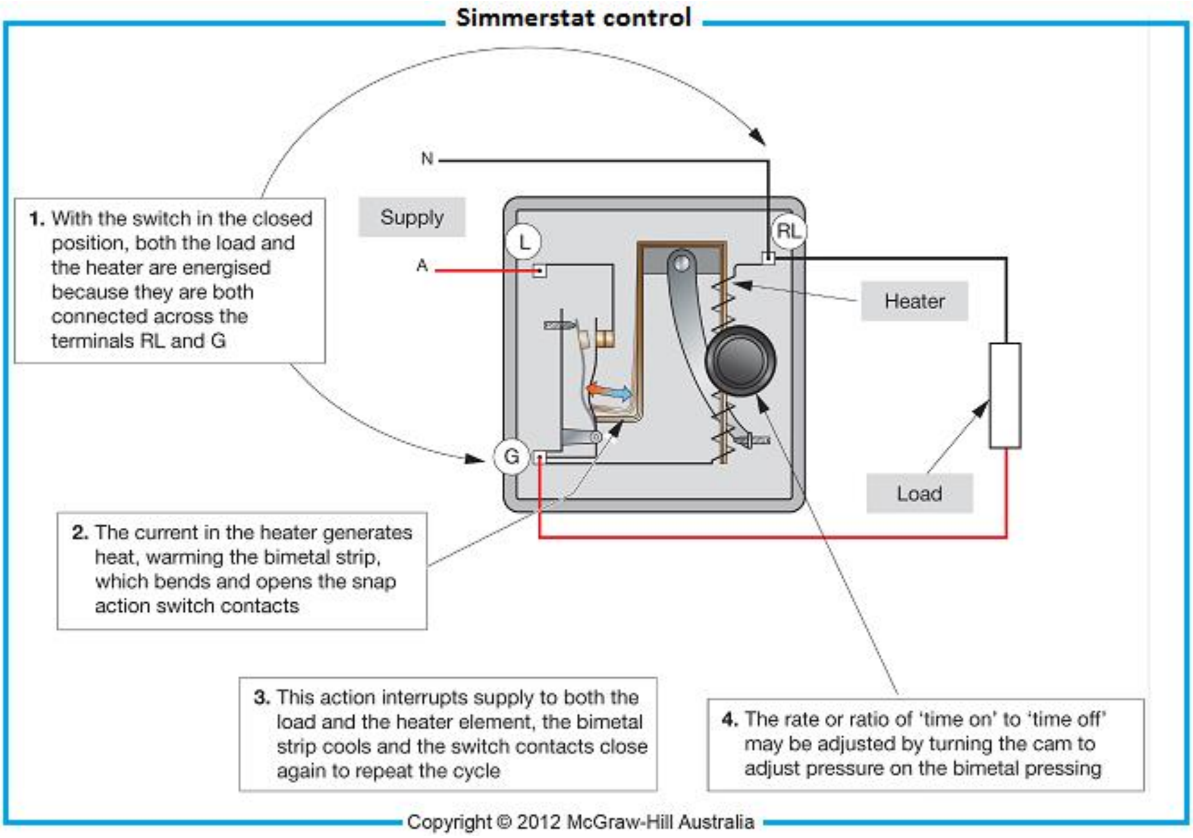
Fixed temperature thermostats

Image © Polytechnic West 2014

Simmerstats

Simmerstats are proportional on/off devices that control the amount of current flow to a load. The ratio of on/off time controls the average power to the load. A dial having a setting between 1 and 10 provides a 50% duty cycle when set to 5.
Simmerstats provide an infinitely variable amount of heat control.

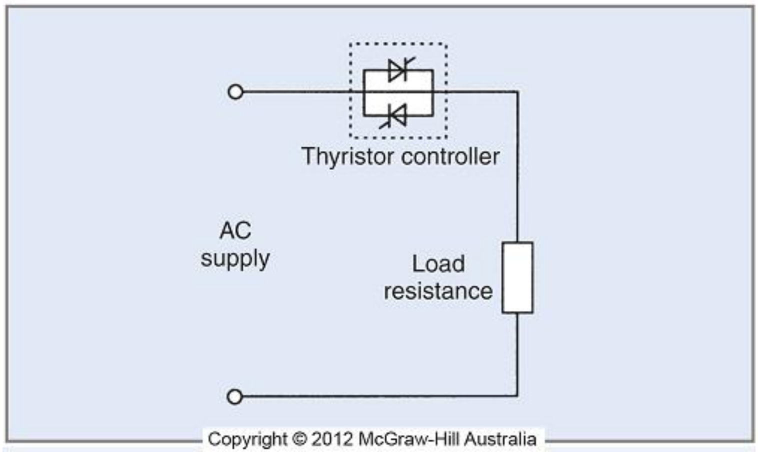
Simmerstats have no reference to the load condition, acting independently to temperature conditions.



The simmerstat consists of a heater that causes a bi-metal strip to bend, thus closing or opening snap action contacts. In a normal state the switch is normally closed, both the load and heater winding are energised. The current in the heater generates heat, warming up the bi-metal strip, which bends and opens the contacts. This interrupts supply to both the load and the heater. The bi-metal strip cools causing the switch to re-close and repeat the cycle.
The ratio between on and off time is adjusted by turning the cam that adjusts the pressure pushing against the bi-metal strip.
The most common applications for the simmerstats is hot plates, water heaters (urns) and pie warmers.
The load on a voltage operated simmerstat is governed by the rating of the switching contacts.

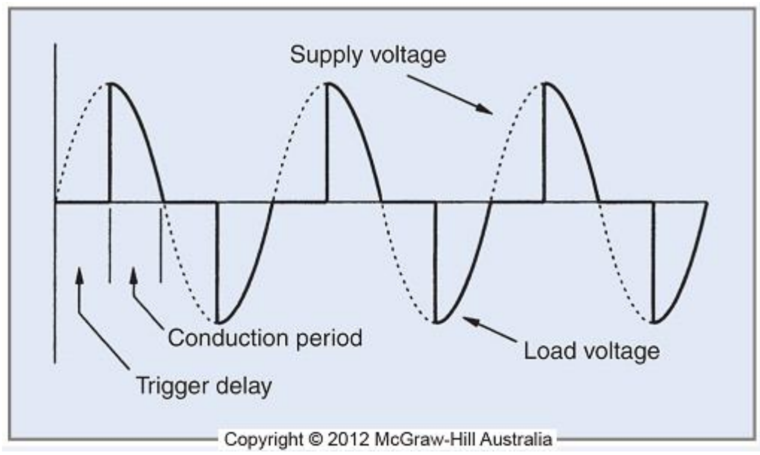
Electronic Controllers

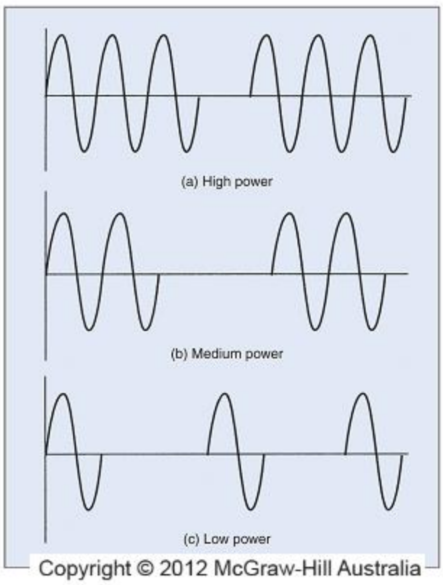
Electronic controllers are solid state circuits, which control an ac load. Functionally these modules produce the same effects as rheostats and variable transformers. They have minimal power loss within the device resulting in higher efficiency and accuracy of load control.



This is an example of one type of solid state controller using two silicon controlled rectifiers back to back to be able to switch on both halves of an ac wave form.

Thyristor Phase Shift Control
Using phase shift control continuously variable power is obtained by controlling the point at which the load controller is triggered on. The load controller switches off at the end of each half cycle. Control of an ac load voltage may be extended to control from 0 to 180 degrees electrical. RFI may be a problem with this type of control.





Zero Crossing Control
The control of a load by zero voltage switching control is used to eliminate electromagnetic interference (EMI) or radio frequency interference (RFI). RFI produces a range of radio frequencies known as harmonics, which interferes with the safe operation of electronic equipment.
Zero voltage switching is a form of on/off control that delivers power to a load in a series of full cycle bursts. The solid state controller switches the load voltage on at the precise moment when the ac voltage passes through zero degrees electrical and off after a number of controlled cycles at the precise moment when it passes back through 360 degrees electrical.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 1B -1**	**Revised 07/2014 UEENEEG033A**

1. What are the three most common devices used to control the heat of electrical elements?
2. What is the main advantage of a double pole three heat switch over a single pole three heat switch?
3. What type of control device provides a simple on or off switching statement?
4. What type of heat control device is most suitable for each of the following situations:-
    - Providing infinitely variable control of the heat produced by a domestic hot plate element.
    - Maintaining the temperature of an electric oven at a set temperature.
    - Operating the high temperature warning light in a motor vehicle when the engine temperature increases beyond the required temperature.
5. How are the elements connected in a Three Heat switching circuit when the switch is in the LOW position?
6. How does a Simmerstat provide a different amount of heat for different settings?
7. What is the most common application for a Simmerstat?
8. What is the operational difference between a Simmerstat and a thermostat?
9. What are the three main types of thermostat (non-electronic type)?
10. Which type of thermostat would be used in a hot water system?
11. How does a bi-metal temperature control device operate?
12. What is the term used to describe the difference between the temperatures at which thermostat contacts open and close?
13. How can a thermostat be tested while in service?
14. Draw a circuit diagram containing a single pole three heat switch and associated heating elements.
15. What is the difference between phase shift and zero crossing power control?
16. What is an adverse effect of using phase control?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity sheet 1B - 2**	**Revised 07/2014 UEENEEG033A**

Single Pole Three Heat Switch

OBJECTIVE

To wire up a single pole three heat switching circuit

EQUIPMENT

Three heat switching project board (Flush or Surface)

Continuity tester

Single phase lead

Two 240 volt 40 watt incandescent lamps

PROCEDURE

DANGER TAG Procedure Required

1. Determine the internal bridges of the three heat switch in each position using a continuity tester
2. Draw a series of diagrams of the internal bridges in the switch in the OFF, LOW, MEDIUM and HIGH positions
3. Determine the phase and neutral terminals then develop a circuit diagram showing the external connections from the switch to the lamps (each lamp represents one heating element)
4. Have your circuit checked by your Lecturer
5. Wire up the project board to your circuit, using the correct colour code for the conductors.
6. Check your circuit for short circuits with a continuity tester
7. Have your wiring checked by your Lecturer
8. Plug the circuit into a 240 volt GPO, switch it on and check for correct operation. Have the circuit checked by your Lecturer
9. Record your circuit, including the internal connections in the switch, in your laboratory notebook, labelling the active and neutral terminals.
10. Switch the circuit off and remove the plug from the outlet
11. Disconnect your wiring and return the equipment to its proper place.

QUESTIONS

1 Name two electrical appliances that can incorporate a three heat switch

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 1B - 3**	**Revised 07/2014 UEENEEG033A**

Double Pole Three Heat Switch

OBJECTIVE

To wire up a double pole three heat switching circuit

EQUIPMENT

Three heat switching project board (Flush or Surface)
Continuity tester
Single phase lead
Two 240 volt 40 watt incandescent lamps

PROCEDURE

DANGER TAG Procedure Required

1 Determine the internal bridges in each position of the three heat switch using a continuity tester

2 Draw a series of diagrams of the internal bridges in the switch in the OFF, LOW, MED AND HIGH positions

3 Determine the phase and neutral terminals then develop a circuit diagram showing the external connections from the switch to the lamps, (each lamp represents one heating element)

4 Have your circuit checked by your Lecturer

5 Wire up the project board to your circuit, using the correct colour code for the conductors.

6 Check your circuit for short circuits with a continuity tester

7 Have your wiring checked by your Lecturer before connecting to the 240V supply

8 Plug the circuit into a 240 volt GPO, switch it on and check for correct operation. Have the circuit checked by your Lecturer

9 Record your circuit in your laboratory notebook, including the internal connections in the switch, and label the active and neutral terminals.

10 Switch the circuit off and remove the plug from the outlet

11 Disconnect your wiring and return the equipment to its proper place

QUESTION

What is the advantage of using a double pole three heat switch over a single pole switch?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 1B - 4**	**Revised 07/2014 UEENEEG033A**

Simmerstat Control

OBJECTIVE

To connect a voltage type Simmerstat into a heating circuit and observe its operation

EQUIPMENT

Simmerstat project board (Voltage type)
Demonstration Simmerstat (Voltage type)
Single phase lead board
Stop clock
Multimeter
One 40 watt incandescent lamp

Diagram

PROCEDURE

DANGER TAG Procedure Required

1 Observe the construction of the demonstration Simmerstat. Note the lettering on the case adjacent to each terminal, and to what part of the Simmerstat each terminal is connected.

2 With the aid of the diagram above, determine how the Simmerstat on the project board is to be wired into the circuit. Make a diagram of your proposed connections and have it checked by your Lecturer.

3 Wire the Simmerstat into the circuit and have your wiring checked by your Lecturer

4 Plug the circuit into a 240 V GPO and test it for correct operation, then switch the Simmerstat to the OFF position.

5 Turn the Simmerstat control knob slowly clockwise until the lamp (load) comes on. Leave the control knob in that position. The lamp should go on and off as the Simmerstat operates. Note the time on and time off and record the times in the Table below. Record the ON and OFF times for that setting over a five minute period.

6 Set the control knob to a slightly higher setting and record the ON and OFF times over another five minute period

7 Leave the Simmerstat in that position and remove the lamp (load). Listen to the Simmerstat and see if it is clicking on and off. Record the result.

8 Calculate the time ON period as a percentage of total elapsed time for each setting.

9 Have your results checked by your Lecturer

10 Switch the circuit off and remove the plug from the outlet.

11 Disconnect your wiring and return all of the equipment to its proper place.

RESULTS TABLE

	Time ON	**Time OFF**	**Percentage of Time ON**
Setting 1			
Setting 2			

QUESTIONS

1 Briefly describe the operation of a voltage controlled Simmerstat

2 Why is a Simmerstat unsuitable for controlling the heat of an electric oven?

3 What is a current controlled Simmerstat

4 Does a voltage controlled Simmerstat click on and off with the load disconnected?

5 What determines the maximum load which may be controlled by any give Simmerstat?

Notes:

Government of Western Australia North Metropolitan TAFE	Solve problems in single and three phase low voltage electrical apparatus and circuits	Study Guide Section 1 Part C	Revised 07/2014 UEENEEG033A

Electrical water heater operation:

Topic 6	Required skills and knowledge:
	• types of water heaters (instantaneous and storage) and their methods of control. • intrinsic safety (pressure relief and thermal cut-out). • testing of over temperature cut-out point of a thermostat. • switchboard requirements to supply a controlled load water heater. • internal circuit of a twin element water heater, and supply connections. • tariffs employed by local supply authorities. • solar heating system and its integration into an installation.

Student Activity	Done	
Read **Section 6.3 Water heating** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 165 to 172		
Read AS/NZS3000:2018 Section 4.8 Appliances producing hot water or steam		

Water heating

Whether the installation is domestic, commercial or industrial water heaters may be grouped as being either:-
(a) Instantaneous heaters or (b) Storage heaters

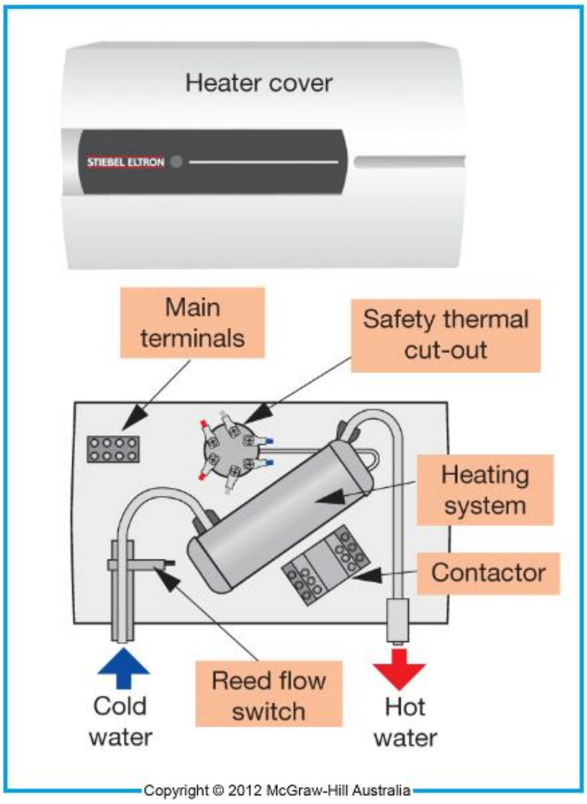
In all cases the water is indirectly or directly heated by a resistance element. The element may be wound on a porcelain bobbin and then enclosed in a metal sheath to indirectly heat the water, or it may be a direct heating type (like a stove element). The temperature of the water is thermostatically controlled. The resulting systems are low maintenance. *(Stokes)*
Domestic installations the maximum temperature of the bathroom water must be limited to 50 degrees Celsius or less to minimise the risk of scalding. This is achieved by the use of a mixing valve.

Instantaneous type HWS:

An instantaneous hot water system provides hot water when required without any storage capacity. Controlled by a flow switch that detects when the hot water tap is turned on it heats the water a it flows.

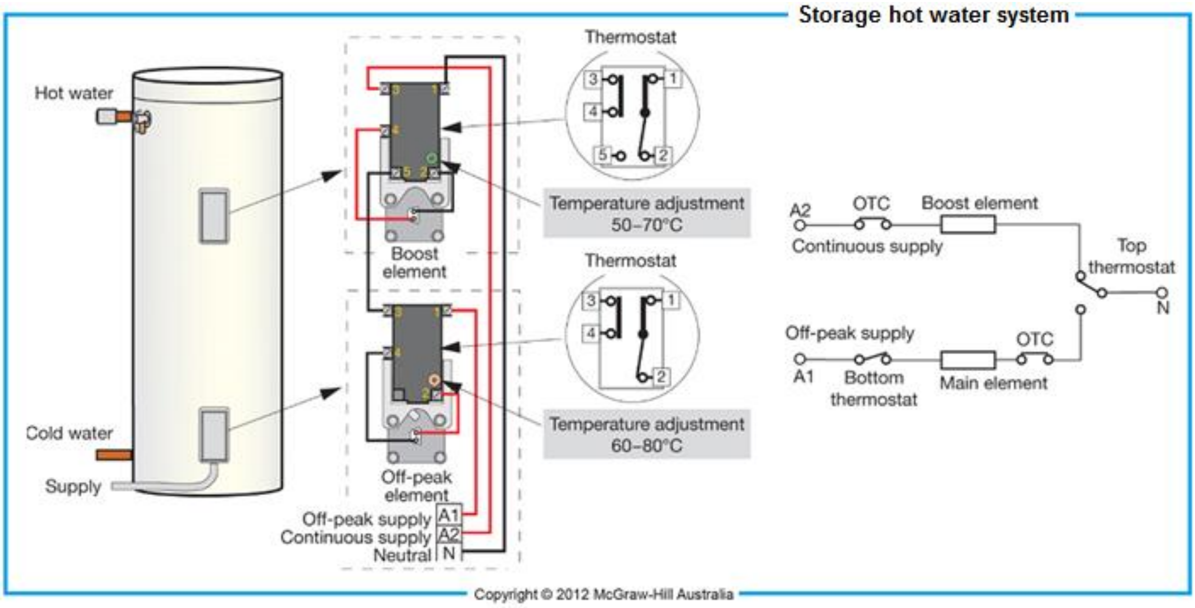
An instantaneous hot water system can be single, two and three phase systems.
They can range in size from 3 to 5 kW for single phase, up to 11 kW for two phase and 27 kW for three phase.

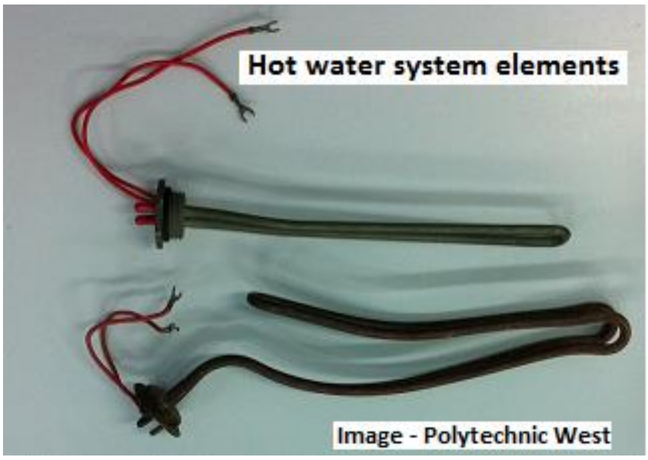
The advantage of the instantaneous system is the reduced energy waste of a storage system.
The dis advantage is that it is only for short period use and places a high current demand on the installation when in use.

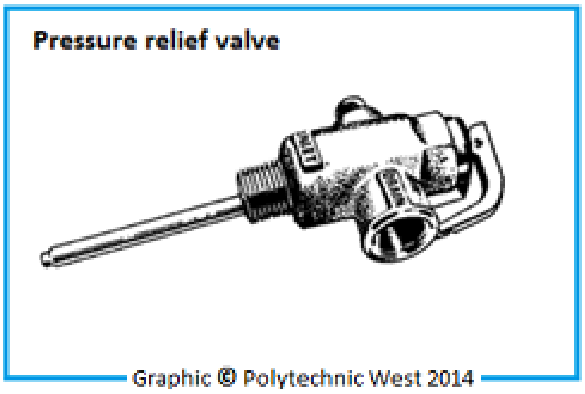


Storage type HWS:
Storage water heaters are available in a range of storage capacity sizes from 25 to 400 litres with power rating from 3 to 4.8 kW. All storage heaters are thermostatically controlled to keep water temperature approximately constant within the delivery rating of the heater.
The most common type is the unvented mains pressure hot water system. This delivers stored hot water at mains pressure. Controlled by a thermostat to maintain a set temperature of above 60° C it is protected by an over temperature cut out switch (OTC) in the electrical circuit and a pressure relief valve. It is recommended to operate the PRV every 6 months to ensure that it is not blocked.

Some heaters incorporate a no volt release.
This is a magnetically operated contactor which drops out when the supply falls below a pre-set value. This is used in multiple installations (such as a block of flats) so that all the heaters do not re-start immediately the supply is restored. This prevents excessive current draw and volt drop in the installation, because each contactor must be started individually.







All types of storage water heater require a sacrificial anode to limit corrosion of the metal components due to electrolytic action. These anodes must be replaced at regular intervals – typically every two to three years.

A typical mains pressure storage water heater may be fitted with an additional booster element installed near the top of the cylinder. The normal and booster elements must be wired for non-simultaneous operation. In all cases the thermostat for the top booster element should be set 10 degrees centigrade lower than the bottom element thermostat to prevent water temperature exceeding 95 degrees centigrade in case of thermostat failure.

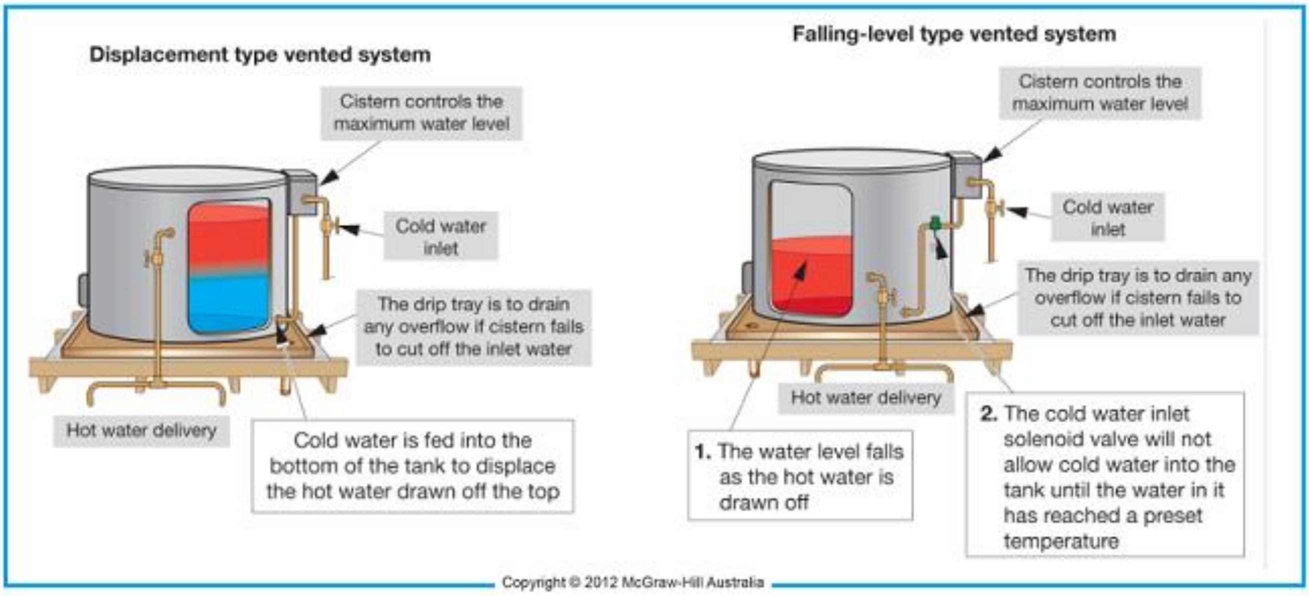
AS/NZS3000 Clause 4.8.2.1 requires every unvented water heater to be installed such that easy access is available to pressure relief devices and terminals of protective equipment to enable readily available adjustment, inspection and operation of these devices.

AS/NZS3000 Clause 4.8.2.2 states that over temperature cut-outs and similar protective devices on unvented water heaters must operate directly in the circuit wiring to the heaters and not be arranged for control through relays or contactors.

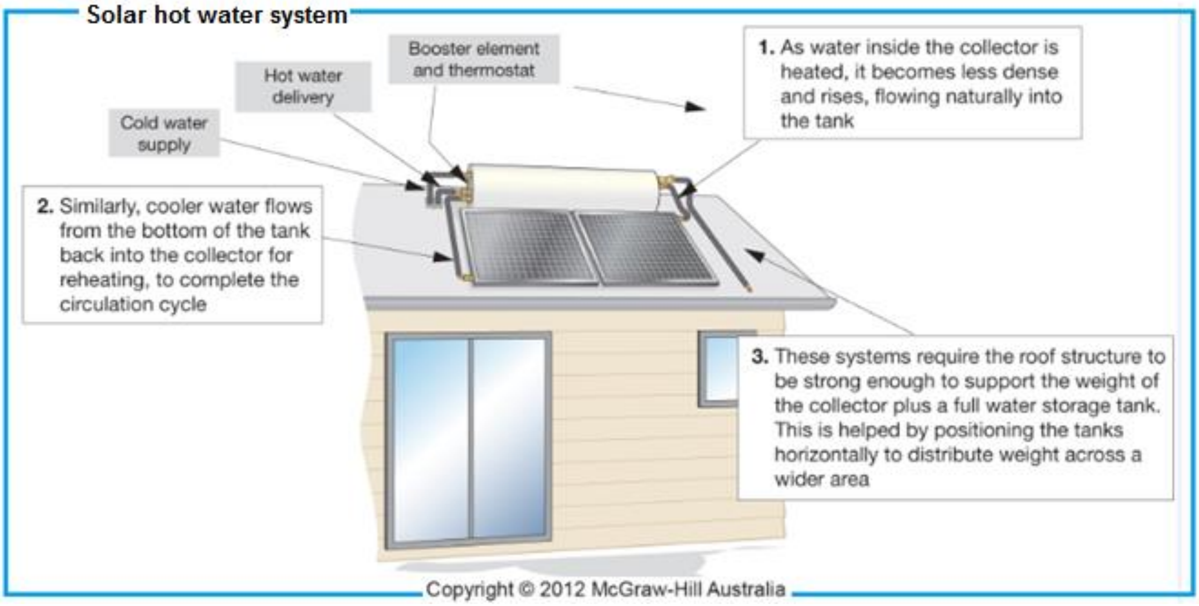
AS/NZS3000 Clause 4.8.2.3 Isolating switch: Every water heater that is fixed wired shall be provided with an independent isolating switch (lockable) installed adjacent to but not on the water heater. The circuit breaker at the switchboard does not fulfil this requirement.

Vented storage hot water systems.

If mains pressure is not available or the mains pressure system is not suitable a vented tank that is usually installed in an elevated position to provide delivery pressure can be used.



Conventional solar systems
A commonly used solar hot water system uses the thermosiphon principle to transfer thermal energy from the solar collector to the storage tank. The tank and collector are usually close coupled. The tank can be situated on the roof next to the panels or it can be a split system where the tank is installed on the outside ground in near proximity to the panels. A pump circulates water from the bottom of the tank to the collector panel on the roof where the water is heated by the solar panels. A thermostatic controller prevents water from being pumped from the tank until it has reached the desired temperature. Water in the collector heated by solar radiation flows to the upper part of the storage tank and is replaced by cooler water from the bottom of the tank. Extra structural timbers are normally required in the roof structure to support the additional weight of a close coupled system.

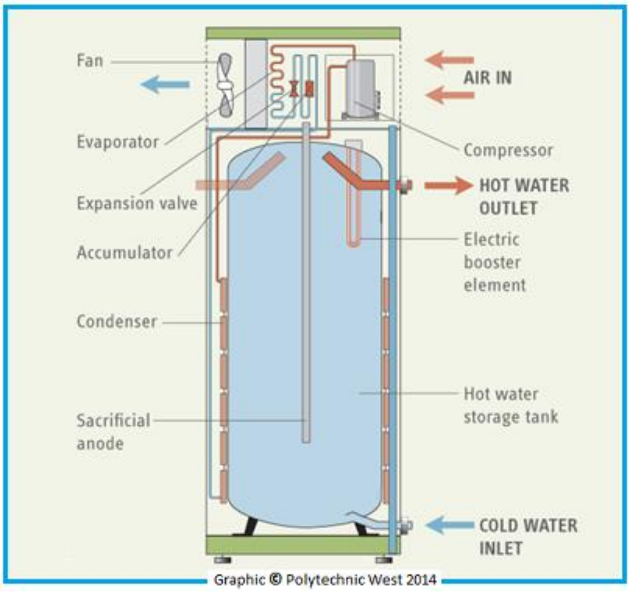


Quantum solar systems

These work on the same principle as a refrigeration circuit, drawing heat out of one space and transferring it to another. The system is available as a split or compact system. In the split system, a water storage tank is located at ground or floor level either inside or outside the house. The solar evaporator plate assembly is mounted on the roof. Vertical wall mounting is also acceptable. Although not essential evaporator plates should be oriented to the north to maximise the available solar contribution to water heating.

Heat pump water heaters

Essentially a heat pump works like a refrigerator in reverse. Unlike a refrigerator that transfers heat from within to the outside air, it transfers the heat energy from the surrounding open air and concentrates it into a high temperature in the water storage cylinder.



This means that the hotter the outside temperature, the more efficiently the system works and the quicker the water is heated.

A common characteristic of heat pump water heaters is the tendency for the evaporator coil to 'ice-up' at low temperatures, thereby wasting energy as the unit goes through its 'defrost' mode, this problem can be overcome by the use of an inbuilt booster element. If at ambient temperatures below 10C the ice build may up on the evaporator coil, it is necessary to stop the heat pump operation and switch over to the booster element (this will occur automatically). The booster element actually consumes less power heating the water at these low temperatures, than a conventional heat pump in defrost mode.

Tariffs for water heaters

Water heaters for use on "off peak Tariff are continuous type, but have a greater storage capacity. This enables them to heat up overnight at a lower tariff (cost) and still provide sufficient water for the installation during the day.
They are automatically switched off during certain parts of the day.

Tariffs from Synergy are available at this website:

http://www.synergy.net.au/docs/Standard_Electricity_Prices_Charges_brochure_MSF.pdf

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 1C - 1**	**Revised 07/2014 UEENEEG033A**

1. What are the two basic types of electric domestic water heating units?

2. What is a typical maximum water storage temperature in a hot water system?

3. Name two safety devices which are fitted to mains pressure storage type electric water heaters.

4. One part of the safety equipment on a mains pressure storage type electric water heater needs to be operated at least once every six months – what is it?

5. Is it permissible to install a water heater without an independent isolation switch? State the wiring rules clause number.

6. Is it permissible to use a circuit protective device such as a circuit breaker to fulfil isolation switch requirements for a single permanently connected wall mounted room heater? State the wiring rules clause number.

7. What is the main advantage of connecting a storage type water heater to an "off-peak" supply?

8. Describe the main difference in operation between storage and instantaneous type water heaters.

9. What type of control device switches the elements in a storage type water heater?

10. What type of control device switches the elements in an instantaneous type water heater?

11. For what reason would storage water heaters in a block of units incorporate a "no volt release" contactor?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 1D - 1**	**Revised 07/2014** **UEENEEG033A**

Complete the review questions for Chapter 6 in Electrical Wiring Practice (7th edition) Vol.2 on pages 185 to 186.

Notes:

Government of Western Australia North Metropolitan TAFE	Solve problems in single and three phase low voltage electrical apparatus and circuits	Study Guide Section 2 Part A	Revised 07/2014 UEENEEG033A

Lighting concepts and incandescent lighting:

Topic 11	Required skills and knowledge:
	• basic concepts of lighting. • terminology, principles and standards relevant to lighting (energy efficiency as per BCA new lamp types and permitted replacements and their efficacy).. • basic types of luminaries. • operation of an incandescent lamp. • types of incandescent lamps. • expected lamp life, colour rendering and efficacy for typical incandescent lamps. • lighting layout in terms of visual comfort and relevant Australian standards

Student Activity	Done	
Read **Section 7.1 Basic lighting principles** Electrical Wiring Practice (7th ed.) Vol.2 Pages 187 to 193		
Read **Section 7.2 Luminaires** Electrical Wiring Practice (7th ed.) Vol.2 Pages 194 to 196		
Read **Section 7.3 Elementary lighting design** Electrical Wiring Practice (7th ed.) Vol.2 Pages 196 to 199		
Read **Section 7.4 Incandescent lamps** Electrical Wiring Practice (7th ed.) Vol.2 Pages 199 to 203		

Read Section **7.1 Basic lighting principles, 7.2 Luminaires and 7.3 Elementary lighting design** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 187 to 199

Lighting Principles and Terminology

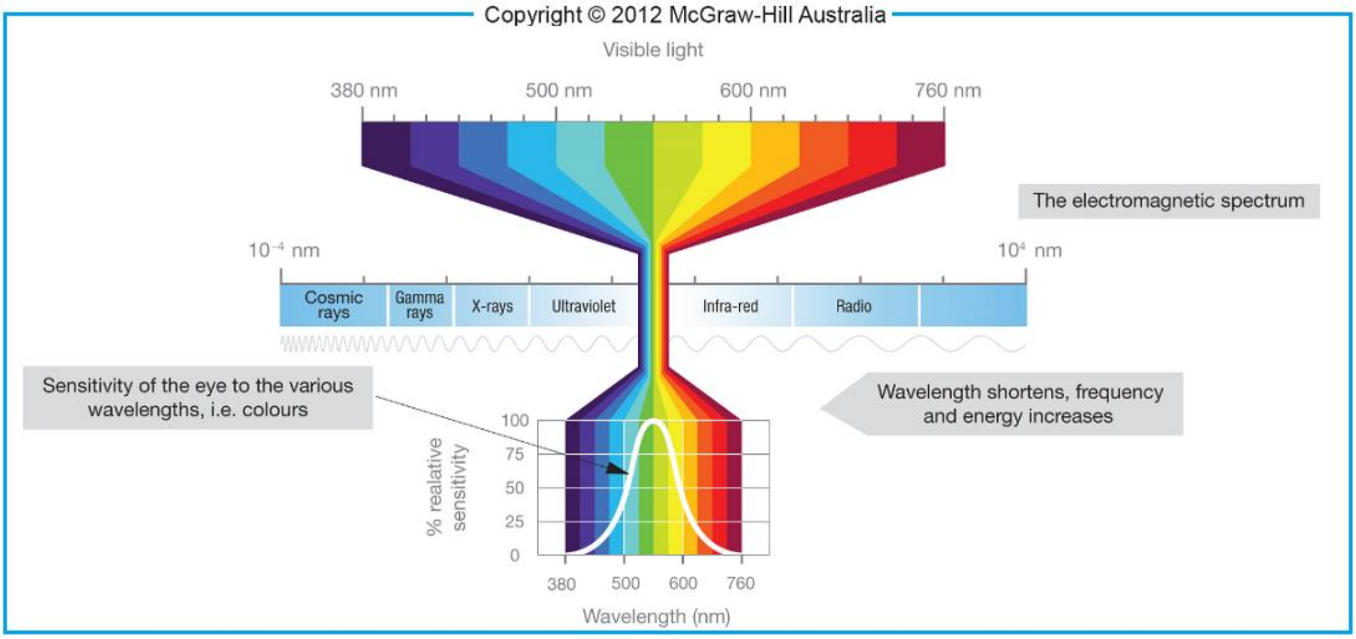
Light

Visible light is a form of electromagnetic energy and can be defined as electromagnetic radiation in that portion of the spectrum to which the human eye is sensitive. The speed of light in a vacuum is 3 x 10^8 m/s (300,000,000 meters per second).

There are two ways of defining a particular radiation - either by the frequency of the radiation or the wavelength.

The Electromagnetic Spectrum

Radiation at different wavelengths (or frequencies) can be shown on what is known as the electromagnetic spectrum.



Invisible Light

On either side of the visible spectrum there are regions of radiation termed the infra-red and ultra-violet regions. Although not visible, each of these regions is of importance in the electrical field and special lamps are manufactured to produce radiation in either of these regions.

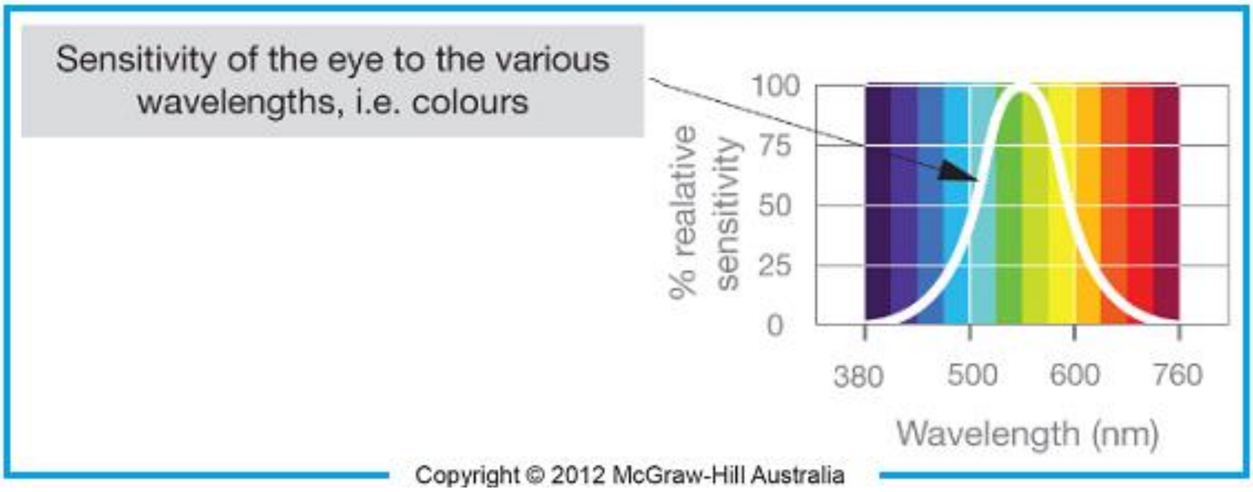
a. Infra-red lamps are used for heating.
b. Ultra-violet lamps are used for sterilisation and detecting fluorescent phosphors in various substances.

Visible Light

Within the visible spectrum there are a number of distinct radiations which are recognised by their characteristic colours. Each of these colours has a separate, distinct frequency and wavelength, (lamp manufacturers often refer to the wavelength when describing the colour output of their lamps). White light is the combination of all the colours of the visible spectrum.

The Visible Spectrum

The human eye is most sensitive in the yellow green region of the visible spectrum at the wavelength of 555 nm (nanometers)



Light can be produced electrically in two main ways:

a. By incandescence where visible radiant energy is produced when sufficient current is passed through a conductor (filament) until it is heated to a point where it glows.
b. By Discharge where an arc is produced in an evacuated, gas filled container.
Both of the methods described result in the manufacture of lamps that emit (give off) a variety of different colours of light.

Vision

(The act of seeing) Vision is relayed to the human senses through the eye by the impact of light waves on the eye retina, and is mainly concerned with distance, form, and colour, where the apparent colour of an object depends partly on the wavelengths of the light waves and partly on the state of the eye. Knowing the terms used when referring to the effect of light on the eye is important.

Terms Associated With Vision

Accommodation: This is the ability of the eye to focus on an object automatically as the distance away varies.

Glare:
Where excessively bright light causes temporary loss of sensitivity and fatigue of the eye.
Glare can be classified under two headings:

a. Direct Glare: Where visual efficiency is impaired when portions of the field of view are excessively bright.
b. Indirect Glare: Where discomfort may be experienced by reflection off a light coloured or shiny surface.

Persistence of Vision: Where the image is retained on the retina of the eye for a short time after the object is removed from the field of vision.

AS/NZS3000:2018 wiring rules defines luminaires and sets out the requirements for the installation of lighting equipment and accessories.

1.4.80 Luminaire (Light fitting): A complete lighting assembly intended to distribute, filter, or transform the light from one or more lamps.
4.5.1 Lampholders, including lampholders incorporated in a luminaire.
4.5.2.3.4 Classification of recessed luminaires

Terms Associated With Light

Working Plane: The working plane is the horizontal, vertical, or inclined plane in which the visual task lies. In the majority of cases the horizontal work plane is assumed to be 850 mm above floor level.

General Lighting: This is normally provided by an arrangement of luminaires which produce approximately uniform illumination throughout an installation on the working plane. No special provision is made for local requirements within the area. A typical example would be a college class-room.

Local Lighting: Local lighting is where a specific task area is illuminated by a luminaire other than those associated with general lighting. A typical example is the light mounted over a drill or lathe in a workshop.

Diffusion Diffusion is the scattering of light rays so that they travel in many different directions rather than in parallel or radiating lines.

Diffused Lighting Diffused lighting utilises the diffusion effect so that the light on the task area comes from many directions, thus reducing harsh shadows.

Diffusion can be is achieved by:

a. Where the light rays of one or more large area light sources are diffused by passing the rays through a diffusing medium such as opal or translucent materials, a prismatic lens, or reflecting them from a matt surface.

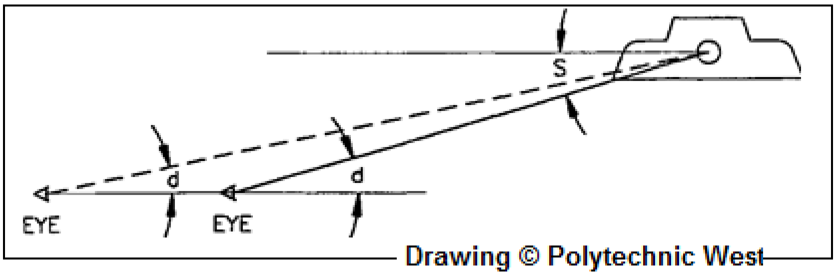
b. By using several small light sources, so that an object near an illuminated surface does not cast a dense shadow on the surface.

Directional Lighting: Directional lighting comes mainly from one direction, with very little diffusion or scattering of the light rays, so that an object placed near an illuminated surface casts a dense shadow on that surface.

Shielding Angle: A luminaires primary function is to direct light to where it is required. A well designed luminaire will also reduce glare by ensuring that lamps are concealed from view whenever the lamps angle of elevation above the horizontal line of sight becomes less than a specified shielding angle. The shielding angle required depends on the degree of glare control desired and the type of lamp used.

S = Shielding Angle

d = Displacement Angle



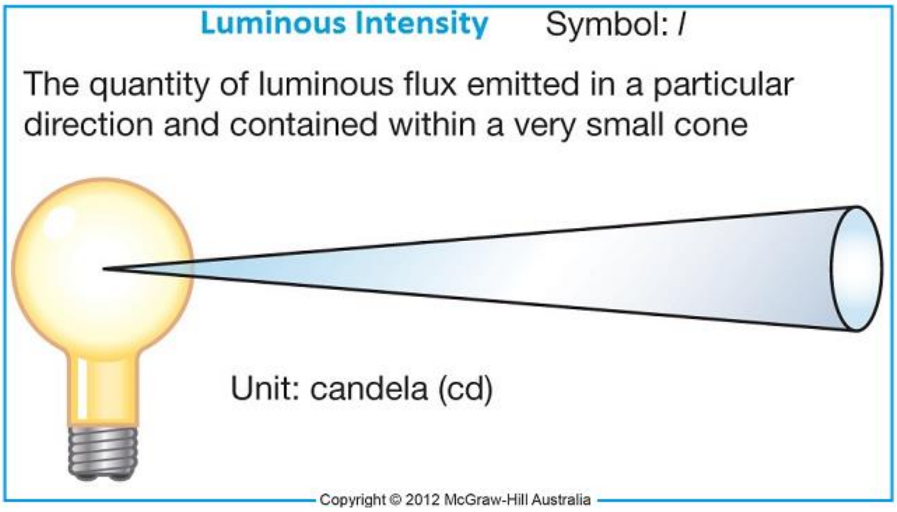
Service Value of Illumination

The amount of light in a given installation will decrease in time due to a drop in light output of lamps, ageing of luminaires, and the accumulation of dust and dirt on fittings, ceilings and walls. These factors are taken into consideration when calculating the 'Service Value of Illumination' which is the mean value of illumination throughout the life of a lighting installation averaged over a particular area.

Brightness: Brightness is the term used to describe how bright a light source or surface is, or where an area seems to emit more or less light, as judged by the human eye.

Brightness cannot be measured in ordinary photometric terms - it is simply a comparison and should only be used to describe the appearance of a source of light.

Lighting Terms and Units



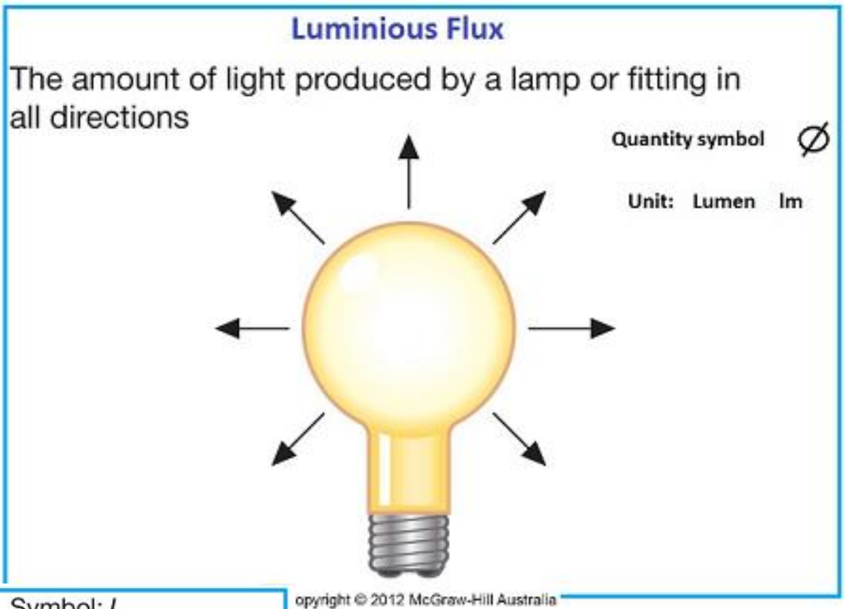
Luminous Intensity

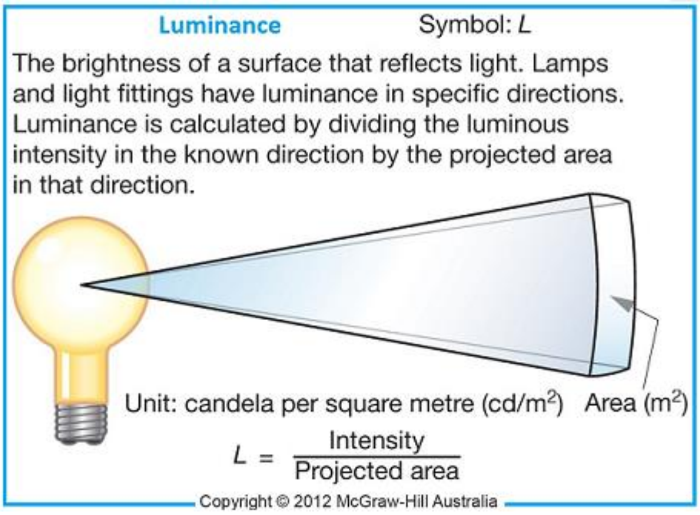
The luminous intensity is radiating in a particular direction

For scientific purposes, one candela is defined as the luminous intensity, in the perpendicular direction, of a surface of 1/600 000 square metre of a black body at the temperature of freezing platinum (2 046.65K} under standard atmospheric pressure. It is to this standard that all light quantities are related.

Luminous Flux

Luminous flux is the amount of light emitted by a light source or luminaire irrespective of the direction in which it is distributed or from which it is received. The light output of lamps and luminaires is given in lumens.





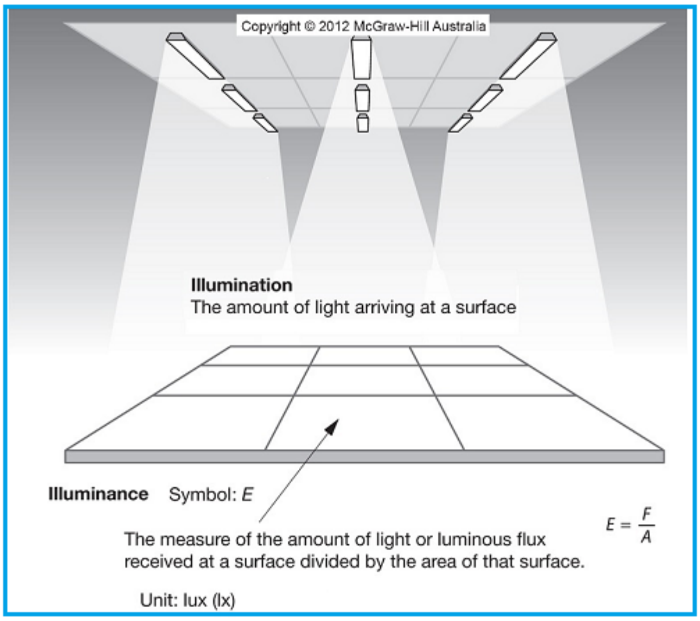
Luminance

Luminance is the luminous intensity of a surface reflecting light, or a light source radiating light. A surface may have luminance by reflecting light. Since luminance is associated with the intensity (candela) the luminance may change with direction.

lluminance

Illuminance is the luminous flux density at a surface. Its unit {lux) is arrived at by the quantity of light (lumens) falling on a surface per unit area (m^2} irrespective of the direction from which it is received. The illuminance on a surface, or at a point, may be provided by a number of sources simultaneously. 1 lux is 1 lumen per m^2. The term 'illumination' is sometimes used in place of illuminance.

Illuminance at the work plane can be a mixture of direct and reflected light, and may comprise of both natural sunlight, and artificially produced electric light.



Illuminance Required

The illuminance required depends on the visual task. Specific recommendations relating to the illuminance required for visual tasks are given in AS 1680 - Interior Lighting and the Visual Environment.

AS/NZS1680 series of standards cover the requirements for lighting principles.

Lighting affects safety, task performance and the visual environment by changing the extent to, and the manner in, which different elements of the interior are revealed.

Safety is ensured by making any hazards visible.

Task performance is facilitated by making the relevant details of the task easy to see.

A lighting system should be so designed and installed as to effectively reveal the task and provide a safe and comfortable visual environment.

The fulfilment of these objectives can often depend on the quality rather than the quantity of the lighting which is provided.

Efficient seeing of the task depend on:

- Adequate illumination of the task
- Freedom from unwanted reflections

- Luminance of the surroundings correctly related to that of the task

A safe and comfortable visual environment depends on:

- Avoidance of excessive illuminance variations
- Absence of direct glare from lamps, luminaires or windows
- An appropriate luminance distribution on interior surfaces
- Use of suitable colours on the main interior surfaces
- Use of light sources with suitable colour characteristics

AS/NZS1680 series of standards sets out the minimum illumination levels required for various types of installations and related tasks.

TABLE D1
RECOMMENDATIONS FOR CIRCULATION SPACES AND OTHER GENERAL AREAS

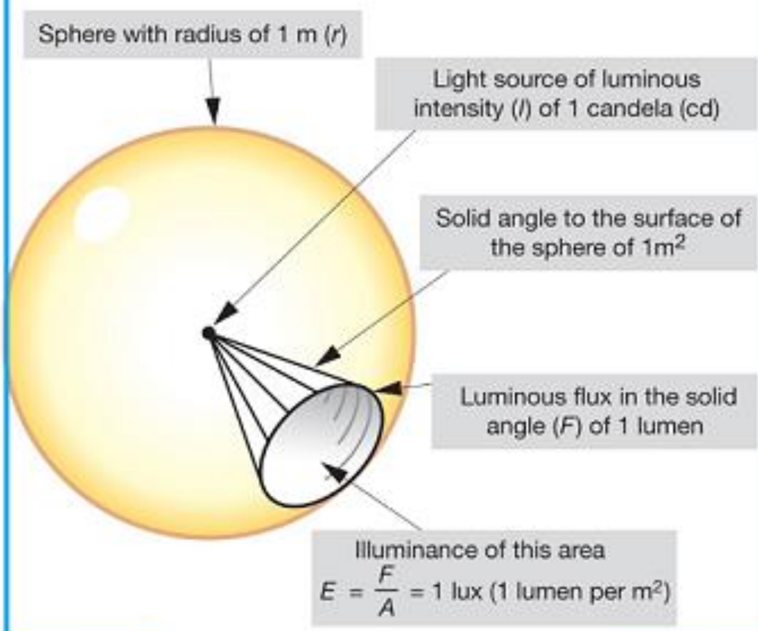
	1 Type of interior or activity	2 Maintained illuminance lx	3 Lamp colour appearance group	4 Lamp colour rendering group (minimum)	5 Maximum glare index	6 Other recommendations and advice
1 1.1	ENTRANCES Entrance halls, lobbies, foyers	160	1, 2	2	—	The illuminance applies at floor level, See additional recommendations in Section 3 of this Standard.

AS/NZS 1680.0:2009	Interior lighting - Safe movement
AS/NZS 1680.1:2006	Interior and workplace lighting - General principles and recommendations
AS/NZS 1680.2.1:2008	Interior and workplace lighting - Specific applications - Circulation spaces and other general areas
AS/NZS 1680.2.4:1997	Interior lighting - Industrial tasks and processes
AS/NZS 1680.2.2:2008	Interior and workplace lighting - Specific applications - Office and screen-based tasks
AS 1680.3-1991	Interior lighting - Measurement, calculation and presentation of photometric data
AS/NZS 1680.4:2001	Interior lighting - Maintenance of electric lighting systems
AS/NZS 1680.5:2012	Interior and workplace lighting - Outdoor workplace lighting

Relationships between Units:

Name	Symbol	Unit	Symbol
Luminous flux	*F*	lumen	lm
Luminous intensity	*I*	candela	cd
Luminance	*L*	candela per m^2	cd/m^2
Illuminance	*E*	lux	lx

With a uniform point source of 1 candela at the centre of a hollow transparent sphere of 1 m radius, the illuminance of each m^2 of the surface is 1 lumen (1 lumen per m^2= 1 lux). The relationship between lighting units is shown.



The surface area (A) of a sphere is calculated by $A= 4\pi r^2$

Therefore the total luminous flux from a uniform point source which has a luminous intensity (I) of 1 candela in all directions can be calculated by:

Luminous flux = $4 \times \pi \times 1$

= $4 \times 3.14 \times 1$

= 12.57 lumens

Luminous Efficacy Symbol: K Unit: Lumens per watt (lm/W)

The luminous efficacy is the ratio of the luminous flux in lumens from a source to the power consumed in watts.
A typical incandescent lamp has an efficacy between 10-20 lm/W.

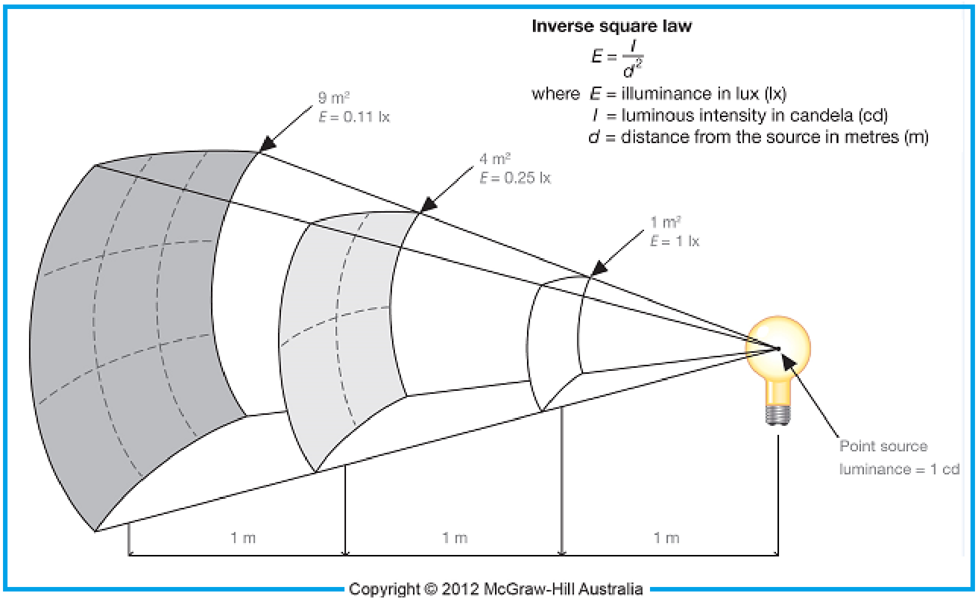
Example:

What is the efficacy of a 500 watt halogen floodlight which has a light output of 10 500 lumens?

10 500 / 500 = 21 lm/W

Inverse Square Law

The illuminance on a surface due to a single concentrated source varies inversely as the square of the distance from the source.



The illuminance 2m from the light source is 0.25 of the illuminance at the point 1m from the light source.

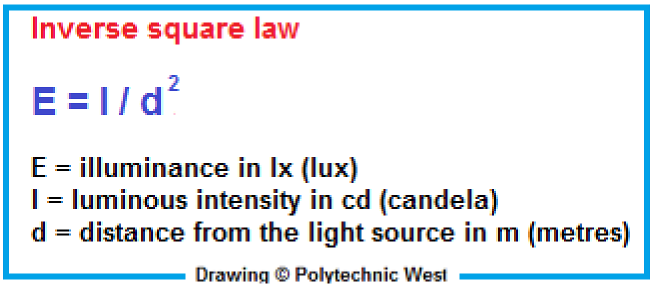
In the previous image the point source had a luminance of 1 cd (Candela)

At 1m distance from the light source the illuminance is lux is:

$1 / 1^2 = 1$ lx

At 2m distance from the light source of 1 cd the illuminance is lux is:

$1 / 2^2 = 0.25$ lx



At 3m distance from the light source of 1 cd the illuminance is lux is:

$1 / 3^2 = 0.11$ lx

Examples

a. What is the average illuminance on a surface situated in a direct line 2 m from a light source of 800 candela?

E = I / d2

= $800 / 2^2$

= 200 lux

b. An illuminance of 400 lux exists on a working plane at a distance of 3 metres from a light source. If the inverse square law is applicable to the situation, what is the luminous intensity of the source?

E = I / d2

by transposition I= E x d2

= 400 x 9

= 3600 candela

General Requirements for Good Lighting

Many factors must be considered in lighting design:

- Cost
- Length of service
- Time that lamps are ON-OFF
- Colour rendering
- Amount of illuminance required for specific tasks
- Elimination of direct or reflected glare
- Type of luminaire

In general the lighting should be so designed and installed as to:

a. Reveal the task in the most efficient manner; and b.
b. Provide a safe and comfortable visual environment.

Efficient seeing of the task depends mainly on:

a. Sufficient illumination of the task.
b. Freedom from reflected glare or flickering lights.
c. Luminance of surroundings correctly related to that of the task.
d. Lighting so diffused and directed as to provide suitable conditions of shadow and reflection at the task.

A safe and comfortable visual environment depends mainly on:

a. Sufficient illumination over the whole room.
b. Correct luminance distribution on interior surfaces.
c. Absence of direct glare from lamps and luminaires.
d. Lighting so diffused and directed as to provide suitable shadow conditions throughout the interior.
e. Light sources with suitable colour properties.

Light Meter

It is often necessary to take measurements of illuminance within an installation and portable light meters are available for this purpose. A light meter generally uses photovoltaic cell coupled to a micro-ammeter calibrated in lux or (lm/m^2).

When light falls on the photovoltaic cell an emf is produced. A current which is proportional to the illuminance will flow through the micrometer, and the instrument can be calibrated to give the illuminance directly in lux.

When using a light meter care should be taken not to cast a shadow over the photovoltaic cell or to expose it to ambient light, otherwise a false reading will be obtained.

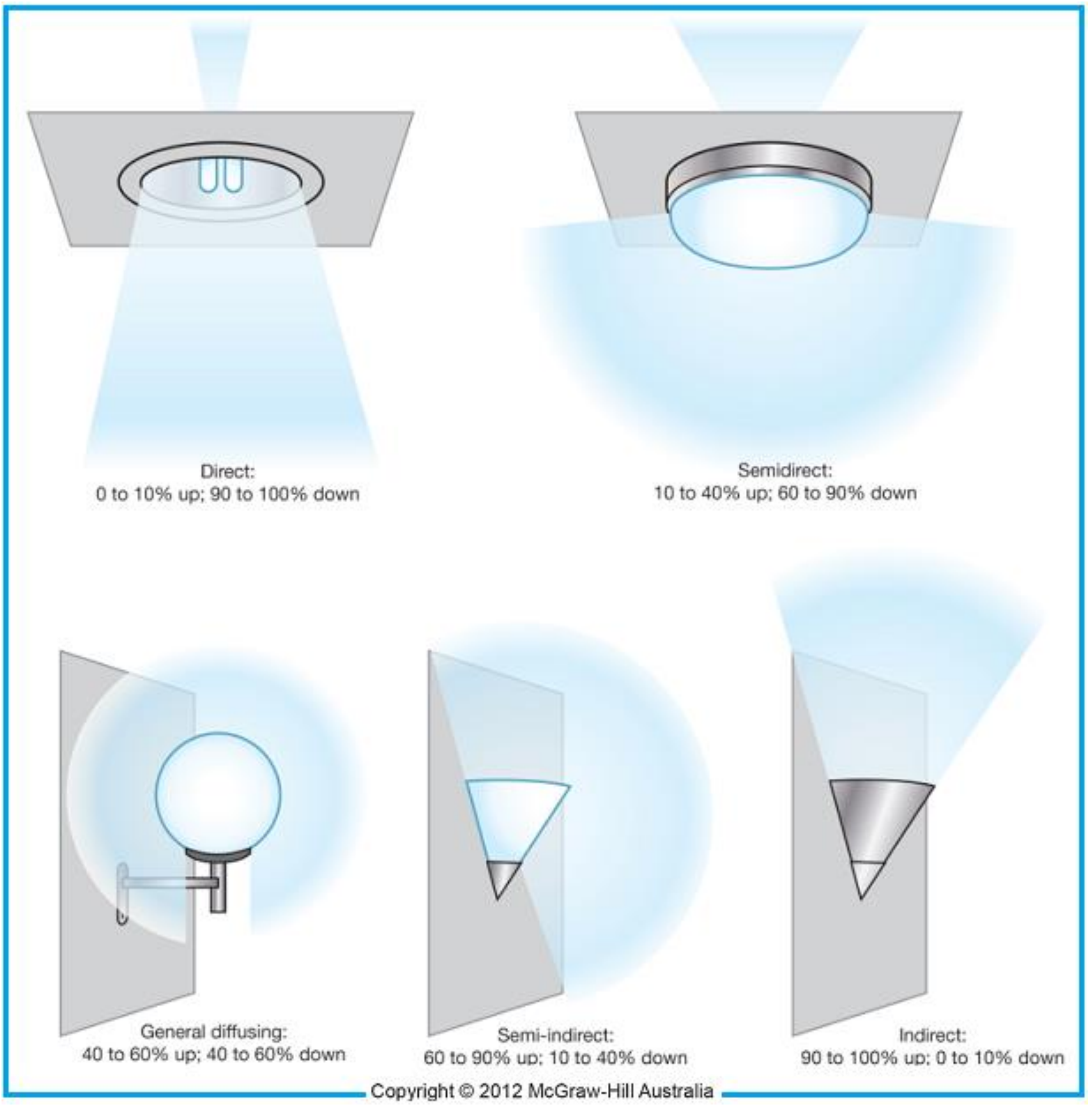
Types of Luminaires

Luminaires are manufactured in various forms to suit different types of lamps, most of them are designed for specific tasks. The two general types of luminaire are functional and decorative.

Functional luminaires are intended to illuminate an object or area so as to provide the best possible conditions for the seeing task with the minimum possible consumption of electrical energy (such as the luminaires in a factory installation). Decorative luminaires provide illumination1 but less emphasis is on illuminating a seeing task and more is on contributing to the decor of the installation (such as a chandelier in a large room).

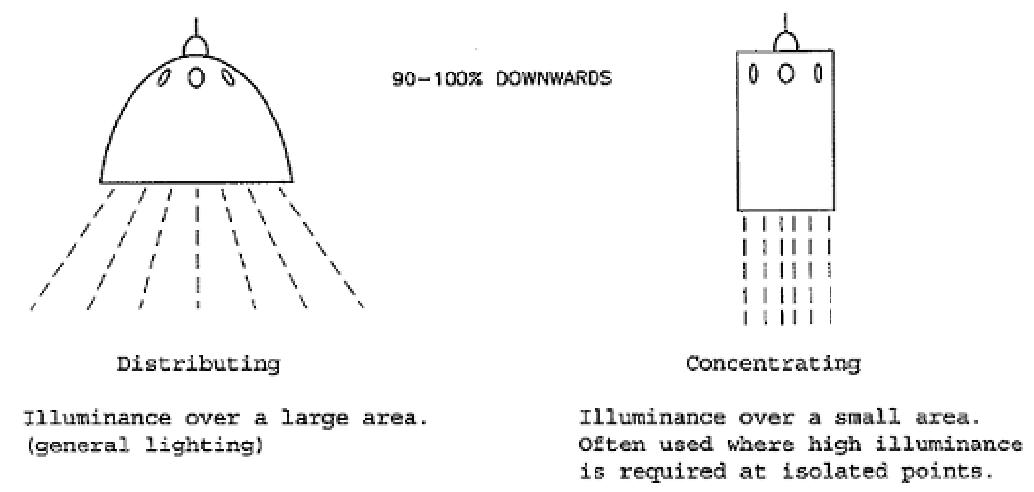
A special type of functional luminaire is usually used for security lighting a large area is illuminated with little regard for the colour of the light.

The basic types of functional luminaires are:



Direct Lighting

Light is directed downwards in the most efficient manner. Very little light is lost in absorption by walls and ceilings. This type tends to create harsh shadows and areas of light and dark particularly when the mounting height of luminaires is too low. Reflectors used with direct lighting are generally classified as Distributing and Concentrating.



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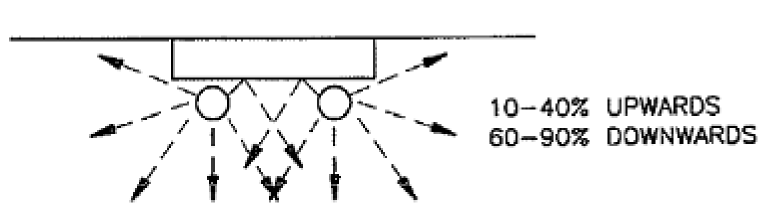
Semi-Direct Lighting

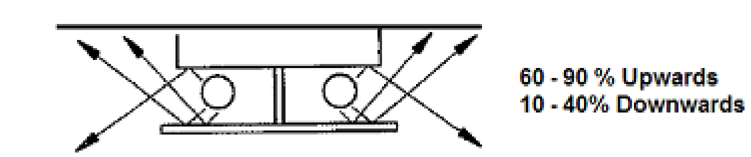
Semi direct lighting retains most of the efficiency of direct lighting where 60-90% of the light emitted from a luminaire is in the downward direction. The remaining 10 - 40% of the luminous flux is emitted upwards. This upward component helps to soften shadows, and reduce contrast between the task area and other sections of the room.



Drawing © Polytechnic West

Semi-indirect Lighting

With this type of luminaire 60-90% of the total flux is emitted upwards, it is then reflected from the ceiling and upper area of the walls to all parts of the room. As only 10-40% of the flux emitted is in the downward direction there is a subsequent loss in efficiency. An even distribution of light is achieved that eliminates most shadows.



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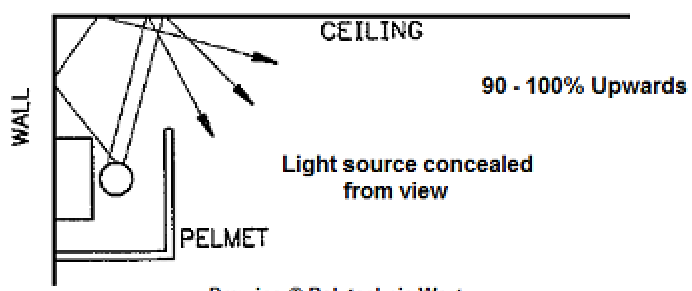
Indirect Lighting

With indirect lighting 90-100% of the luminous total flux is emitted into the upper hemisphere. Practically all of the light is reflected from ceilings and walls, and the primary light source is concealed from view. A diffused, evenly spread light is obtained but again with a loss of efficiency. It is important to have clean, reflective, ceilings and walls for indirect lighting to be effective.



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The Building Code of Australia (**BCA**) introduced changes in 2010 in terms of energy consumption from lighting per m^2 of floor space in domestic installations.

The new requirements are:

- 5 watts per m^2 of lighting for indoors
- 4 watts per m^2 of lighting for outdoor including verandas
- 3 watts per m^2 of lighting for garages

These new lighting levels can be achieved by the use of energy efficient lighting that is now available.

Lamp Comparison

Lamp Type	Luminous Efficacy (Lumen/Watt)	Colour rendering	Correlated Colour temperature	Expected life
Incandescent	13	100	≤2700K	1000hr
Tungsten Halogen (MR16) 12 Volt	22	100	≤3000K	2000 hr
Tungsten Halogen (MR16) 240 Volt	22	100	≤3000K	2000 hr
Tungsten Halogen (MR11)	22	100	≤3000K	2000 hr
IRC tungsten Halogen (MR16)	28	100	≤3000K	4000hr
Compact Fluorescent integral ballast $_1$	68	82	2700K to 6500K	10000hrs
Compact Fluorescent separate ballast $_2$	58	87	2700K to 6500K	10000hrs
Linear Fluorescent T8 – 36Watts Electronic Ballast	94	85	2700K to 6500K	15000hrs
Linear Fluorescent T5 – 36Watts	90	85	2700K to 6500K	15000hrs
LED $_3$	22 to 60	0 to 90	3000 to 6500K	

Notes:
1 The efficacy varies with lamp size and from brand to brand
2 The efficacy varies with the type of control gear used
3 The characteristics of LEDs varies with brand, model, colour, colour rendering and enclosure

Image- Polytechnic West 2014

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 2A -1**	**Revised 07/2014 UEENEEG033A**

Complete the following questions

1. What type of energy is light?
2. What is the wave-length of visible light on the electromagnetic spectrum?
3. What is the name of the type of invisible light which exists off the low frequency end of the visible spectrum?
4. What is the name of the type of invisible light which exists off the high frequency end of the visible spectrum.
5. What are the seven colours of the visible light spectrum?
6. What type of invisible light can cause permanent damage to the eyes?
7. What is the name given to an electrical device which houses an illuminating lamp and its associated control or mounting components?
8. What is the name of the part of a luminaire which "breaks up" the light so that it is distributed over a wider area and in many directions?
9. What is the unit of measurement for luminous flux?
10. What is the unit of measurement for luminous intensity?
11. What is the quantity symbol for luminous flux?
12. What is the unit symbol for the unit of measurement of luminous flux?
13. What is the quantity symbol for luminous intensity?
14. What is the unit symbol for the unit of measurement of luminous intensity?
15. What is the unit or measurement for illuminance or illumination?
16. What is the quantity symbol for illuminance or illumination?
17. In what units is luminance usually expressed?
18. What is the quantity symbol for luminance?

19. In what units is luminous efficacy usually expressed?

20. What is the name given to the term used to compare the electrical input power to the luminous flux produced by a given lamp?

21. What is the name of the device used to measure the illumination or illuminance on a given object?

22. What is the name given to the physical law which governs the variation in illumination on an object as the distance from the light source varies?

23. What precaution must be taken when taking a reading with a light meter?

24. If the average flux density on a 1 square metre surface is 100 lux when the surface is 1 metre from the light source, what would be the average flux density if the light source was moved another 1 metre away from the surface?

25. In what units is a metric light meter calibrated?

26. Name the term used to describe the colours visible to the human eye?

27. What is meant by the terms “Direct” and “Indirect” lighting?

28. What type of light will result in the softest shadows?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 2A -2**	**Revised 07/2014 UEENEEG033A**

Read **Section 7.4 Incandescent lamps** Electrical Wiring Practice (7th ed.) Vol.2 Pages 199 to 203.

Incandescent Lamps

Many different types of lamps are made that fall into two main categories:

- Filament
- 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.

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)

There are variations of each basic type, each with its own particular application. The different types can be compared on the basis of:

a. efficacy - lumen output/wattage input

b. life average

c. colour rendering

d. cost - initial and running cost e.

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

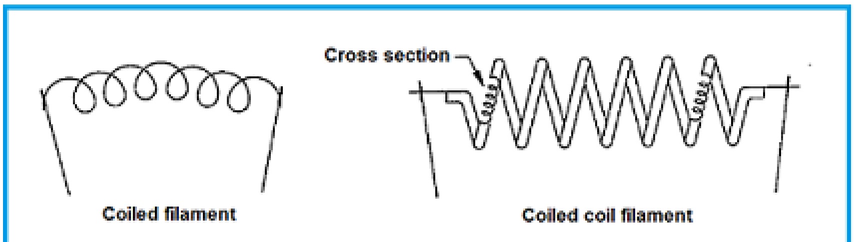
Incandescent lamps produce light as a result of the heating effect of an electric current flowing through a filament wire. When the temperature of the wire is raised sufficiently, visible light is emitted. A predominantly 'red' light is produced by incandescent lamps.

In normal air the filament will evaporate due to its high operating temperature. Enclosing the filament in an evacuated glass envelope limits the evaporation to an acceptable level.

Filament Construction

Incandescent lamps have coiled filaments made of tungsten. Tungsten is used because of its high melting point, and relatively low evaporation rate at high temperatures.

Coiling the wire effectively reduces the overall length of the filament and creates more heat by the mutual heating between adjacent turns.Secondary coiling (coiled coil) will raise the filament efficiency by 20%, but it has the disadvantage of being less robust than the single coil. Raising the temperature of the filament will produce a whiter light. The ratio between the hot resistance of the filament and the cold resistance of a typical incandescent lamp is around 12 to 1, so the power rating cannot be determined from the cold filament resistance.



Typical tungsten fillaments

Drawing © Polytechnic West

Gas Filled Lamps

When a gas such as argon or nitrogen is used in an incandescent lamp it has the effect of cooling the tungsten filament. This cooling action reduces the evaporation rate of the tungsten, arid enables a filament to be run at higher temperatures for an equivalent life of the vacuumed lamp with increased light output.

Clear glass lamps are often the source of glare. A much softer light is produced by coating the internal surface of the glass envelope with a material which as the effect of diffusing the light from the filament. These lamps are commonly called, frosted, pearl, and silica coated.

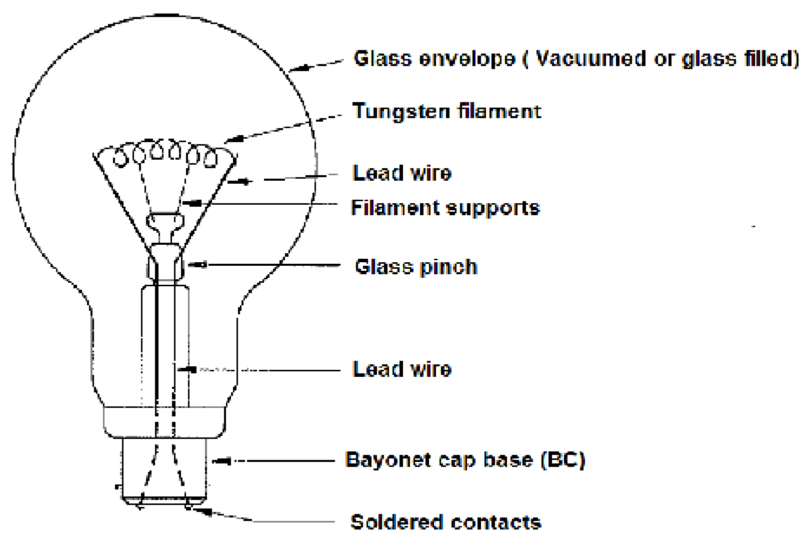
Incandescent lamps that have been in service for a considerable time becomes slightly blackened on the inside of the bulb wall due to filament evaporation. When this does occur the lamps is said to have reached the end of its useful life. The rated life of an incandescent lamp is 1000 hours.

Premature blackening can also result from applying a higher voltage than the designed value. A 5% increase in voltage will give approximately 20% increase in light but the lamp life is considerably reduced by 50%.

Incandescent Lamp Types

General Lighting Service (GLS) This lamp is the type used extensively in domestic, factory and office installations. A contributing factor to their wide acceptance is their low cost and ease of installation. GLS lamps are available with bayonet cap and Edison-screw up to 200 w and goliath Edison-screw up to 1500 w. Their light output varies according to the particular type with an efficacy range between 8 and 18 lumens per watt.

Construction of a typical GLS lamp



Drawing © Polytechnic West

Special Service (Rough service)

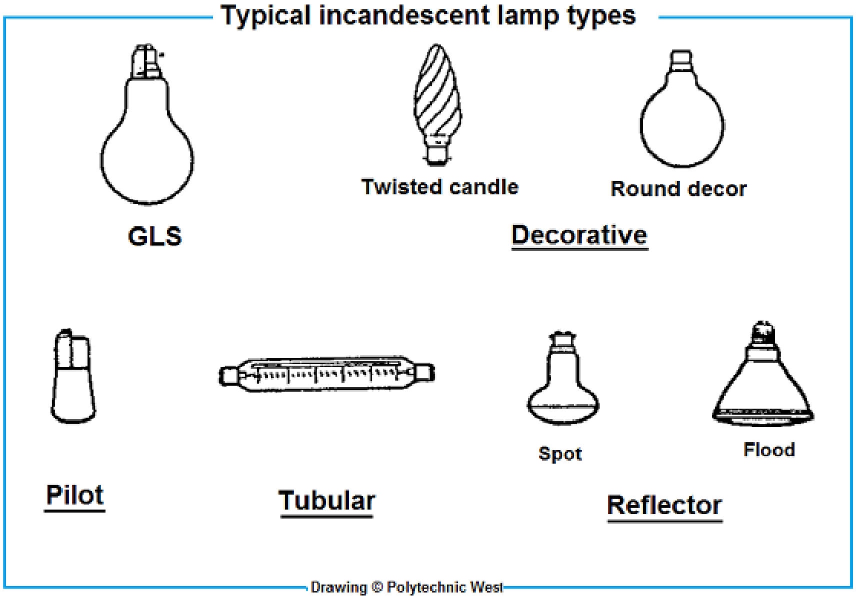
Similar to the GLS lamps in construction, but with a more robust filament. They have the ability to withstand vibration and shock. They have a slightly reduced efficacy with an increase in life rating from 1000 hours to 2000 hours.

Decorative

Decorative lamps are available for use in chandeliers, bed lamps, brackets, etc. They are made in a variety of shapes, and generally their efficacies are low, being more for effect than providing efficient illumination.

Pilot Lamps

These lamps are used extensively in situations where space is restricted and little light required. They find applications in signs, switchboards, refrigerators, cupboards, etc.

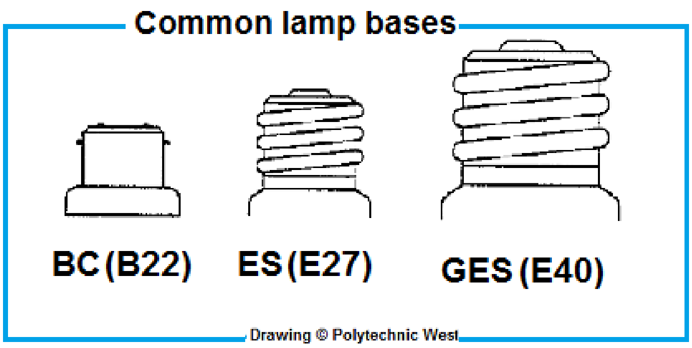


Tubular Lamps (Strip-lights)

The small diameter and high luminous intensity of tubular lamps make them well suited for illuminating show cases, pictures, aquariums and mirrors. The filament extends over the entire range of the lamp producing a uniform long strip of light.

Base Configurations

There are numerous base configurations available but those most applicable to mains operated incandescent lamps are shown in Figure 4 - 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) avail le from 300 W to 1500 W.

Other types of lamp bases are listed below.

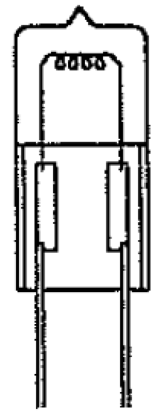
small bayonet cap	SBC
bayonet cap	BC
bayonet cap - 3 pin	3 pin BC
candelabra screw	CAND
small edison screw	SES
edison screw	ES
goliath edison screw	GES

Tungsten Halogen Lamps

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.

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.

Single ended tungten halogen lamp

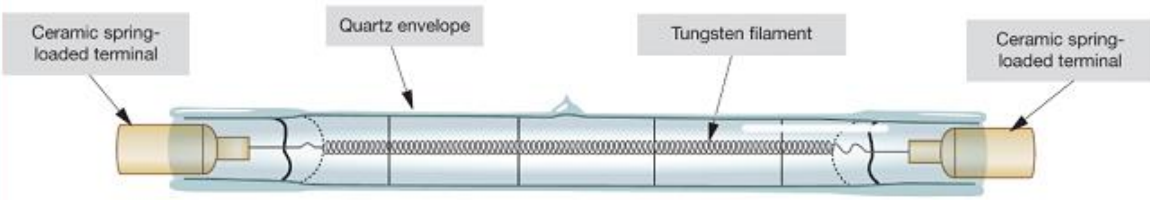


Drawing © Polytechnic West

When a trace of the halogen chemical family, such as iodine is added to the inert gas with which the lamp is filled, a chemical action is induced. This action is often called the regenerative cycle.

The regenerative cycle takes place when the tungsten, which evaporates from the filament, combines with the iodine additive to form molecules of tungsten iodide. The cooling effect of the bulbs quartz wall returns these molecules back into the high temperature zone of the filament, where the tungsten is deposited back on to the filament and the halogen is released to recommence the cycle. The regenerative process allows the filaments to operate at a higher temperature than incandescent lamps with no blackening of the glass wall.

A halogen (iodine or bromine) is added to the normally inert gas filling, and the envelope is maintained at a high temperature to establish a regenerative cycle: the evaporated tungsten combines with the halogen, which, on contacting the filament, returns the tungsten to it. The quartz envelope must only be handled with the sponge cloth supplied with each lamp. Any moisture or dirt on the envelope, such as from touching with bare hands, can cause the envelope to break when the lamp is switched on.



No auxiliary equipment is necessary, the light output is maintained at an almost constant level throughout lamp life, and the lamps are small and compact; for example, a 500 W GLS lamp has 100 times the volume of a 500 W tungsten halogen lamp. Reduction in the size of the lamp reduces the size and weight of the luminaires, allowing precise control of the light output, with good colour rendition.

Mounting Tungsten Halogen Lamps

When mounting or handling halogen lamps the following points should be observed:

a. The mounting position is often critical. Double ended {linear} lamps have a recommended horizontal mounting position plus or minus 5% degrees. Any variation of the mounting angle will not allow the halogen cycle to operate correctly and result in early lamp failure.

If unsure - check with the lamp manufacturer's specifications.

b. Do not mount halogen lamps where they are easily accessible. Their operating temperature is considerably higher than conventional incandescent lamps and if touched when they are in operation severe burns could result.

c. Do not mount halogen lamps where vibration is present. Vibration of the lamp when it is in operation will cause early failure.

d. Do not handle halogen lamps with bare hands. Touching the glass with bare fingers leaves grease deposits which devitrifies the quartz (causes it to return to crystal) at the operating temperature. If the glass is touched with bare hands it must be cleaned with alcohol before it is switched on.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet** **2A - 2**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. Which type of incandescent lamp has the higher luminous efficacy – vacuum or gas filled?

2. What term is usually used to describe the “size” of an illuminating lamp?

3. What do the abbreviations BC ES and GES stand for when used in relation to illuminating lamps?

4. What is the approximate ratio between the cold' resistance and the 'hot' resistance of an incandescent illuminating lamp?

5. What type of incandescent lamp has a glass envelope which must not be touched with bare fingers?

6. What is the power factor of a typical incandescent lamp?

7. What is the special requirement for connecting edison screw lamp holders according to the wiring rules?

8. What does the abbreviation GLS stand for when used in relation to incandescent lamps?

9. What are two general categories of lamps or luminaires?

10. What is the major disadvantage of an incandescent lamp?

11. What special requirements must be considered when mounting double ended or linear-type tungsten halogen lamps.

12. What is the power factor of a typical incandescent lamp?

13. What is the special requirement for connecting goliath edison screw lamp holders according to the Wiring Rules?

14. What two conditions could be indicated if a failed incandescent lamp has a thin black film on the inside of the glass envelope?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity** **2A - 3**	**Revised 07/2014 UEENEEG033A**

Incandescent Lamp Characteristics

Objective

To compare the HOT and COLD resistance of an incandescent lamp.

Equipment

100 watt incandescent lamp with lampholder or project board. Multimeter.
0-300 V a.c. voltmeter.
0-1 A AC ammeter.
Single phase variable transformer (Variac). Single phase lead.

Procedure

Danger Tag Procedure Required

1. Take all details of the lamp provided and record in the table.
2. Measure and record the cold resistance of the lamp.
3. Draw a circuit diagram of the lamp connected to the output from a single phase variable transformer, with instruments to measure the line voltage and line current.
4. Connect the circuit in accordance with your circuit diagram.
5. Check the circuit for shorts with the multimeter.
6. Have the circuit checked by your Lecturer.
7. Energise the circuit and test it for correct operation.
8. Adjust the Variac so that the lamp is off (zero volts).

9. Increase the voltage in 50 V steps. At each step note and record the current reading. Enter your results in the table.
10. Complete the table with the calculations for the lamp’s hot resistance and wattage.
11. Switch the circuit off and remove the plug from the outlet.
12. Have your results checked by your Lecturer.
13. Disconnect your wiring and return all of the equipment to its proper place.

Results Tables

Table of Lamp Details

Filament type	Vacuum or gas filled	Voltage	Wattage	Cold Resistance

Measurements and Calculations

Volts	Line Current	Calculated Resistance	Calculated Power
0v			
50v			
100v			
150v			
200v			
240v			

Questions

1. How do you account for the difference in the calculated resistance at 240 volts and the actual measured resistance of the lamp?

----

2. Calculate the initial current flow when the lamp is connected to a 240 volt supply (i.e. when the filament is cold) -use the measured value of resistance in your calculation.

----

3. The current calculated in Question 2 and the current reading obtained at the 240 V step vary. How much greater is the calculated current than the measured current?

----

4. Why do incandescent lamps fail more often when they are initially switched on than when they are operating?

----

5. What is typical luminous efficacy for a standard gas-filled incandescent lamp?

----

6. What are two possible causes of slight blackening of the inside of the clear glass envelope in an incandescent lamp?

----

7. Was the light output from the lamp directly proportional to the applied voltage as the voltage was varied?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 2 Part B**	**Revised 07/2014 UEENEEG033A**

Fluorescent low intensity discharge lighting:

Topic 12	**Required skills and knowledge:**
	• types of low intensity discharge lamps. • expected lamp life, colour rendering and efficacy for typical types of low intensity discharge lamps. • operation of low intensity discharge luminaires including their control equipment. • Australian Standard and local requirements for low intensity discharge lighting. • methods for satisfying Australian Standards and local supply authority requirements regarding low intensity discharge lighting.

Student Activity	**Done**	
Read **Section 7.7 Fluorescent lamps** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 213 to 216		
Read **Section 7.10 Luminaire and lighting circuits** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 221 to 224		

Read Section 7.7 Fluorescent lamps in Electrical Wiring Practice (7th ed.) Vol.2 Pages 213 to 216
Read Section 7.10 Luminaire and lighting circuits in Electrical Wiring Practice (7th ed.) Vol.2 Pages 221 to 224

Flourescent lighting

The fluorescent lamp uses an electric discharge in mercury vapour at very low pressure to produce ultra violet radiation. This radiation is converted to visible light by a fluorescent powder phosphor coating on the lamp wall.

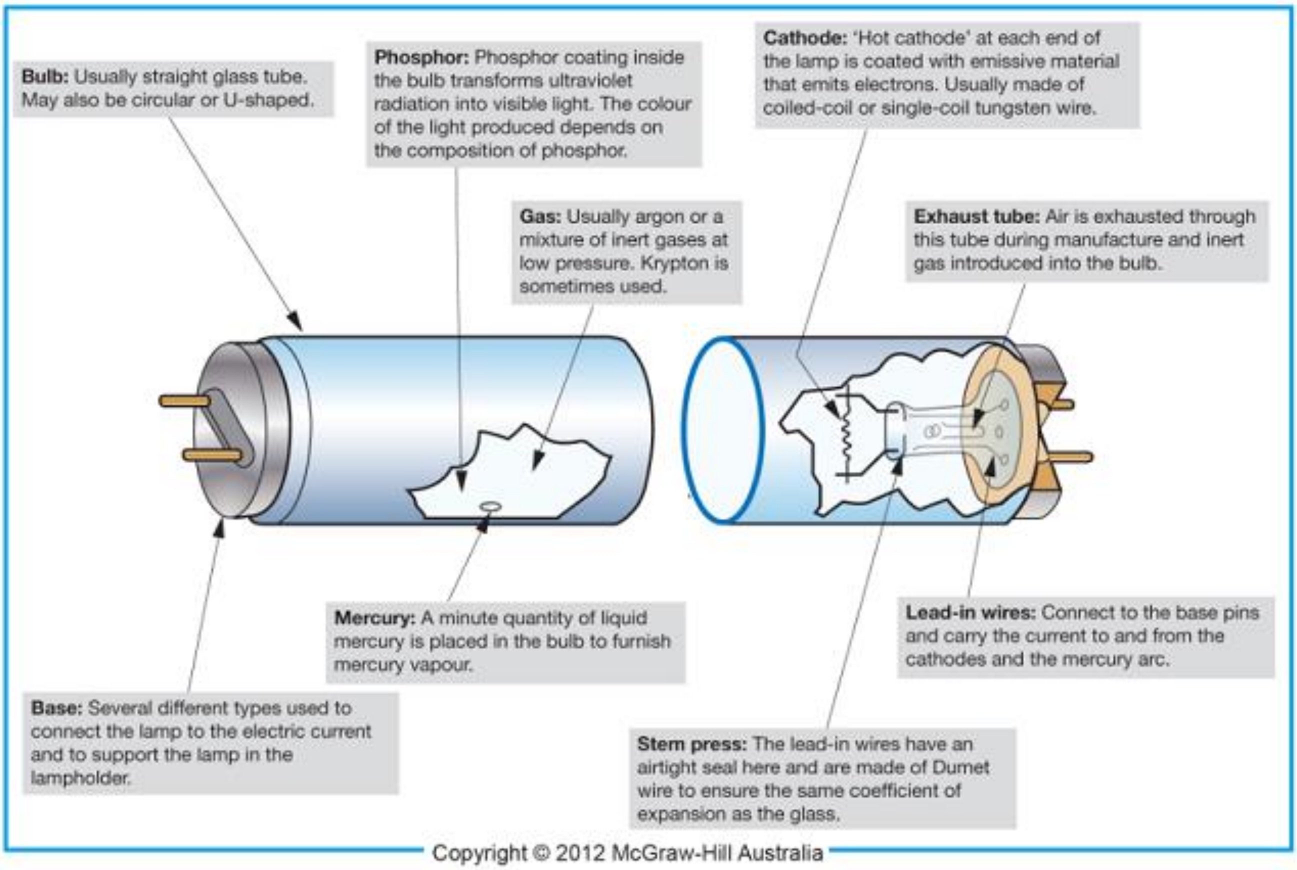
Lamp Construction

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 .

The inert gas argon is added to the mercury vapour to assist starting since the vapour pressure of the mercury is very low.

The types of phosphors used 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.



Cathodes

Cathode construction varies slightly between different manufacturers, but as they are of the hot type' all are made of tungsten and are normally in the form of a coiled coil.

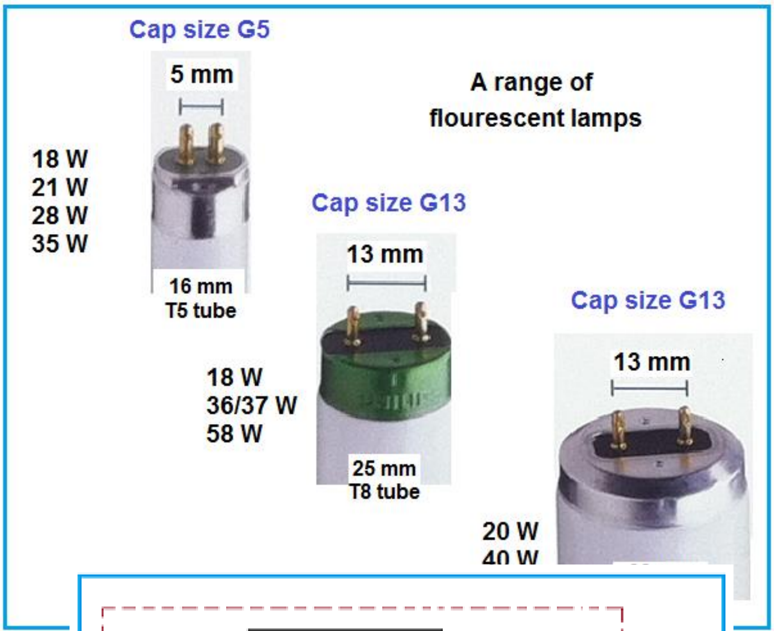
By braiding together very thin strands of tungsten wire to form the coiled cathode, a much greater emission of electrons is obtained. Coating the cathode with an emissive material is a further aid in achieving effective electron emission.

Cathode shields are often used to trap evaporation from the cathode during life which, helps to prevent black marks forming at the end of the tube and to reduce flicker.

Fluorescent lamps are usually referred to by their power rating in watts, or their nominal length in mm.

Typical sizes of standard 240 volt straight fluorescent lamps are:

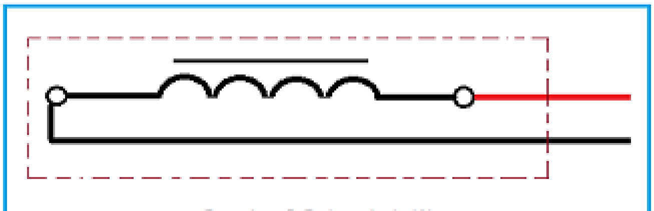
- 18 watt 600 mm
- 36 watt 1200 mm
- 58 watt 1500 mm



Auxiliary Control Equipment

The conventional fluorescent lamp on a.c. requires the following control equipment.

a. Ballast or choke



Drawing © Polytechnic West

A fluorescent tube ballast is an inductive coil would 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. In most cases they also provide an inductive kick to aid striking. The reactance of ballasts vary to suit a particular tubes rating, e.g. 1.8 W, 36 w etc.

b. Starter Switch

The function of the starter switch is to accurately time the pre-heating of the lamps cathodes until the proper starting conditions are reached with a minimum loss of electron emissive materials from the filament.

Photo © Polytechnic West

Thermal glow type starters are the most common starter in use today. It is plugged into a holder mounted in, or near to, the lamp unit and is usually contained in a plastic case which also houses a small radio interference capacitor.

Starter Operation

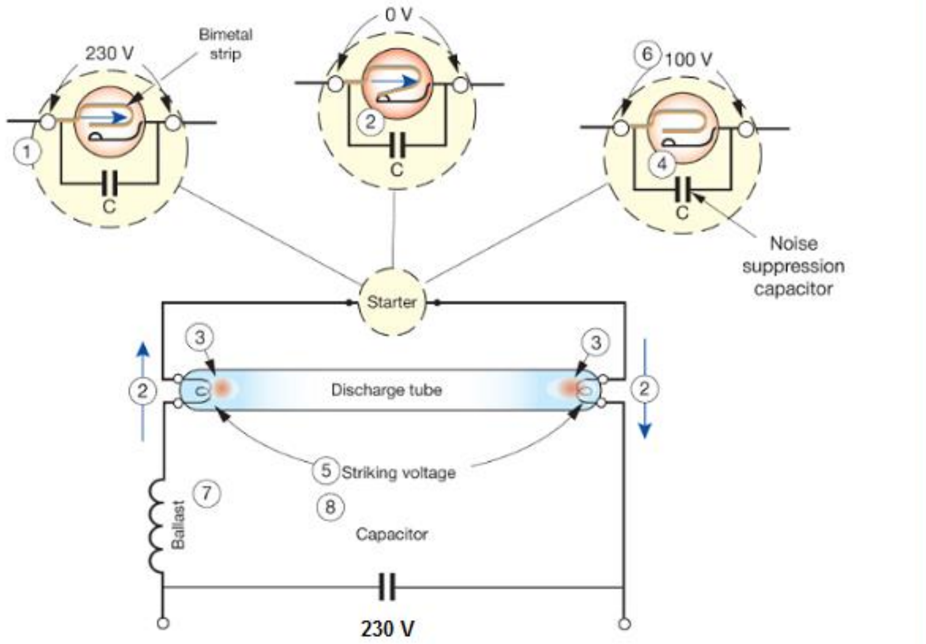
When sufficient voltage is applied to the connecting pins an electrical discharge occurs between the normally open contacts through the neon gas (starter glows). The heat developed from the discharge will cause the bi-metallic contact to bend and close. With the contacts closed the arc is extinguished and with the source of heat removed the bi-metallic contact cools and returns to the normally open position.

Several types of thermal glow type starters are available with ratings to suit a particular lamp size. Care should be taken to match the starter with the lamp in accordance with manufacturer's instructions.

Alternative methods of starting are being developed one such method is a solid state starter suitable for lamps up to 18 w. With this type of starter the characteristic blinking of a fluorescent tube when starting is eliminated.

Most 240 volt fluorescent lamps require a ballast to provide the high starting voltage and limit the running current. Since the ballast results in the circuit having a lagging power factor a power factor correction capacitor must be included in the circuit to correct the power factor to more than 0.8 lagging. A typical power factor correction capacitor for a 36 watt fluorescent unit has a capacitance of about 3.5 microfarads.

1. When the circuit is first switched on, 230 V appear across the contact gap of the starter, ionisation takes place and the gas in the starter glows, giving it the name of 'glow-type starter'.
2. The energy dissipated in the gas warms the bimetal strip, which bends and makes contact with the other electrode to form a series circuit consisting of the ballast and the two filamentary electrodes.
3. Current flowing through the filaments causes them to heat up and produce a cloud of electrons surrounding the filaments.
4. After a short period, the bimetal strip in the starter cools sufficiently (as the glow discharge disappears when the bimetal strip closes) and breaks the circuit at the contacts.
5. The sudden interruption of the current through the ballast causes it to produce a high induced (striking) voltage, which initiates the arc through the tube by ionising the argon gas it contains.
6. The tube is now operating in series with the ballast, while the starter is in parallel with the tube. The voltage across the tube is low (about 100 V for a 36 W tube), and this voltage across the starter contacts is not sufficient to ionise the gas in the starter, so it remains open ready for the next start.
7. The ballast, being in series with the lamp, now limits the power in the circuit to that of the tube rating.
8. The ballast, which is highly inductive, causes a low power factor and hence an increase in supply current; the capacitor corrects this by improving the factor to an acceptable level.



The efficacy of fluorescent lamps varies from 50-90 lumens per watt according to the colour capabilities of the lamp (see table of tube applications).   A life rating of 7500 hours is normal for tubes that are not frequently switched on (once in three hours).

Frequent starting of fluorescent tubes will release more electron emissive material from the cathodes than when they are operating continuously, until a point is reached where the voltage available to induce striking of the lamp is no longer sufficient.

A typical 240 volt 36 watt fluorescent unit draws a current of about 0.25 amps with a power factor correct on capacitor fitted. If the power factor correction is disconnected the line current increases to about 0.5 amps with no significant change to the light output or the power consumed. If the power factor capacitor is faulty it should be replaced with another of the same type a 240 volt fluorescent unit must not be operated without a capacitor because of the high line current.

Application Table

Typical Colour Name	Efficacy	Colour Rendering	Effect	Application
Daylight	80 lm/W	Fair	Cool	General.
White	75 lm/W	Fair	Intermediate	High output with white light.
Warm White	90 lm/W	Fair	Warm	Where a warm atmosphere is required.
Natural	55 lm/W	Fair	Intermediate	General display lighting.
Warm White Delux	50 lm/W	Fair	Warm	Similar to incandescent lighting.
Special Daylight	44 lm/W	Fair	Cool	Suitable for colour matching tasks.

Drawing © Polytechnic West

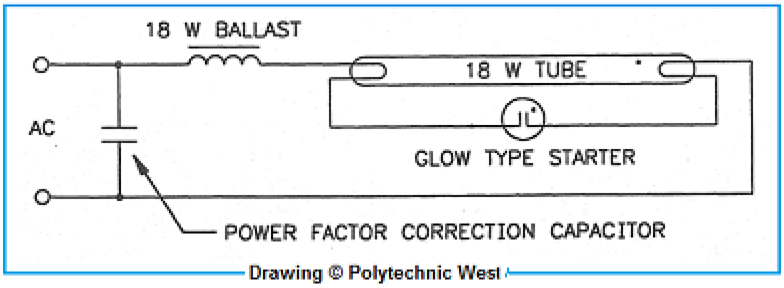
Fluorescent lamps are widely accepted in commercial, industrial and domestic installations due to their high luminous efficacy, long life, low surface brightness and adaptability for various lighting arrangements. Although an incandescent lamp installation is initially less expensive than an equivalent fluorescent lamp, it consumes approximately three times as much electricity.

A compact type of 240 volt fluorescent lamp is available as a direct replacement for a GLS incandescent lamp (without any additional control equipment). A 15 watt compact fluorescent lamp gives about the same light output as a 75 W incandescent lamp with a life expectancy about 8 times greater. Although the initial cost is greater, the overall energy use is significantly less with these types of lamp. Typical sizes range from 9 watts to about 25 watts.

Typical Fluorescent Lamp Circuits

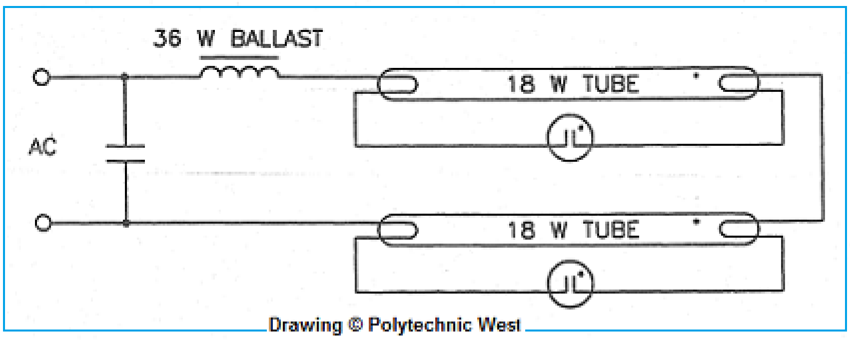
Single 18 W Switch Start

Conventional glow switch starter 18 w or universal. Ballast and tube to match. Power factor correction capacitor required.



Twin 18 W switch start

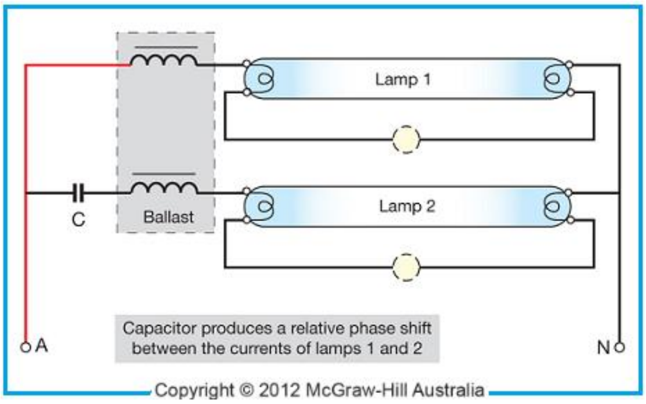
Conventional 20 W glow switch starters. Two 18 W lamps in series require a 36/40 W ballast.



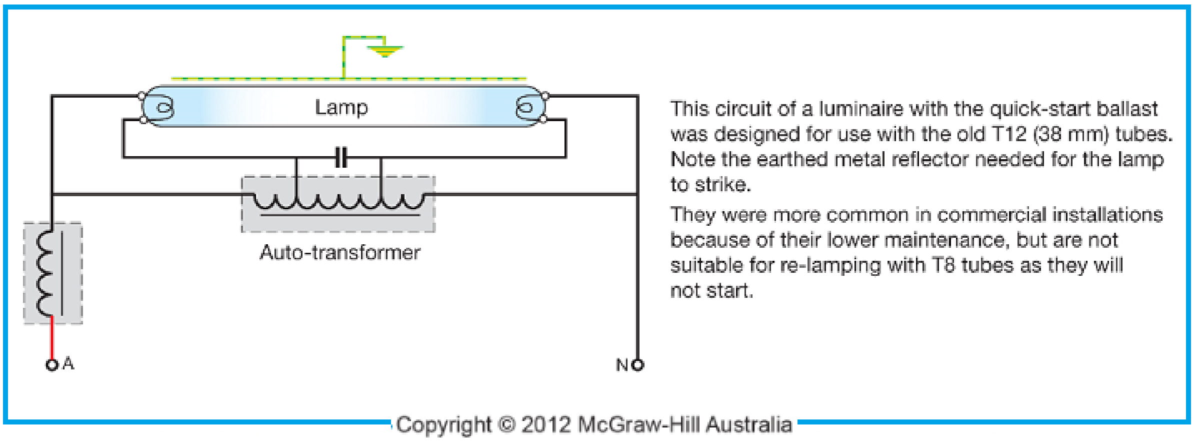
Lead Lag Circuit Switch Start

Two individual circuits are used. Lamp 1 is a standard circuit with a lagging current. Lamp 2 has a capacitor connected in series which produces a leading current to that of lamp 1.

The circuit is used to reduce the stroboscopic effect inherent in fluorescent lamps. The current through each lamp is out of phase so each lamp reaches full brilliance at a different time.



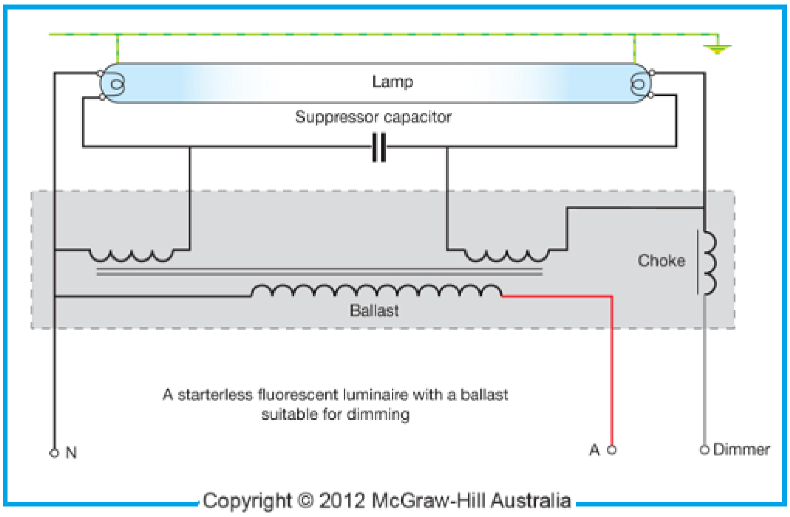
Instant Start Circuits



An instant start or quick start circuit is one in which the lamp lights after a very short delay without flickering. Their circuits do not generally use a starting switch.

Switchless Starting

The starting voltage required for fluorescent tubes is partially dependent on the electrical resistance of the lamp's surface and is at a minimum when the resistance is either high or Lamps used in switchless circuits are of the low resistance type.



Low resistance lamps are obtained by running a metallic strip down the side of the lamp that must be connected to earth to provide a high potential gradient between one cathode and earth to assist ionisation and starting. A normal tube used in a metallic fitting which is earthed will often perform the same function.

Lamps in Service

Although the life rating of fluorescent lamps is typically 7500 hours they are subject to ageing. After 3000 hours running time a depreciation of luminous flux of 15-20% can be expected. Where a high luminous output is required it is advisable to change the lamps before they fail. A lamp usually fails when all of the emissive material has been removed from one or both cathodes.

Blackening at the tube ends normally indicate the lamp is at the end of its useful life, premature blackening can also be caused by high or low voltage, faulty starting, frequent switching and loose contacts

Most circuits which have direct heating for the cathodes can be dimmed using a special circuit which incorporates a typical electronic lamp dimmer.

The Stroboscopic Effect

Pulsating light is a feature of discharge light sources and is directly linked to the frequency of the a.c. supply. A discharge lamp connected to a 50 Hz a.c. supply will actually flicker at a frequency of 100 Hz (once every half cycle). Although the flickering of the lamps cannot be normally detected by the eye the effect can be noticed when a pulsating light illuminates a moving object.

The stroboscopic effect will cause rotating and reciprocating machinery to appear to be running at speeds other than their actual speeds, or in extreme cases to be stationary.

Where discharge lighting is to be used over rotating machines precautions must be taken to eliminate the stroboscopic effect. There are several methods used, they are:

a. Connect adjacent lamps to different phases.
b. Use a lead lag circuit.
c. Use a small percentage of incandescent lamps.
d. Use lamps with a longer persistence of light (some phosphor coatings have a long afterglow).

Special lamps are available that make use of the stroboscopic effect, such as engine timing lights and stroboscopes.

Stroboscopes are devices that provide pulses of light at a controlled frequency, and can be used to check the speed of rotating or reciprocating machinery. They are also used for special effects in the entertainment field.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 2B - 1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. What type of cathodes are used in a standard 36 watt fluorescent lamp?

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 line current and the luminous efficacy 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. A fluorescent lamp has black rings at each end of the tube and it blinks on and off when operating. What is the most likely cause?

6. The ends of a fluorescent lamp glows brightly when it is switched on but the lamp does not strike. What is the most likely cause?

7. Draw a circuit of a typical single 36 watt fluorescent lamp.

8. Draw a circuit of a typical twin 18 watt luminaire supplied from a single 36 watt ballast.

9. What are two functions of the ballast in a 36 watt fluorescent unit?

10. What is the practical cure for a fluorescent lamp which continually blinks on and off after it has been in service for about three years?

11. Define the term “Stroboscopic effect”.

12. With regard to conventional fluorescent lamp circuits, what item of auxiliary control equipment, other than a ballast or starter switch, is needed to satisfy Supply Authority requirements?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 2B - 2**	**Revised 07/2014 UEENEEG033A**

36 Watt Fluorescent Lamp Characteristics

Objective

To connect up a typical single 36 watt fluorescent lamp circuit and observe its operation.

Equipment

Single 36 watt fluorescent project board.
Multimeter.
0-100 watt wattmeter.
0-1A ac ammeter
Connecting leads.
Single phase-lead.
Manufacturer's data relating to fluorescent lamps.

Procedure

Danger Tag procedure required

1. Draw a circuit diagram of a single 36 watt fluorescent lamp connected to a 240 volt a.c. supply. Include instruments to measure the line voltage, line current and power.

2. Connect the project in accordance with your circuit diagram.

3. Check the circuit for shorts with the multimeter.

4. Have the circuit checked by your Lecturer

5. Energise the circuit and test for correct operation.
6. Measure the line voltage, line current and the power and record the readings in the results table.
7 Switch the circuit off and remove the plug from the outlet.

8. Disconnect the power factor correction capacitor.

9. Check the circuit for shorts with the multimeter.

10. Have the circuit checked by your lecturer

11. Energise the circuit and record the line voltage, line current and circuit power in the results table.

12. Have your results checked by your Lecturer.

13. Switch the circuit off and remove the plug from the outlet.

14. Disconnect your circuit and return all of the equipment to its proper place.

Result Table

	Line Voltage	Tube Voltage	Starter Voltage	Filament Voltage	Line current	Power
Corrected						
Uncorrected						

Questions

1. Explain the operation of the circuit in detail, refer to your test results where necessary.

----

2. What prevents the starter from striking once .the tube is operating?

----

3. What are the two main functions of the choke or ballast?

----

4. What effect did it have on the operation of the circuit when the capacitor was disconnected?

----

5. What are two advantages of fluorescent .lamps over incandescent lamps?

----

6. Calculate the cost of operating an installation containing 100 36 watt fluorescent lamps for one hour at the current domestic rate for electrical energy.

7. What size cable would be required to supply an installation consisting of 100 36 watt fluorescent lamps if the power factor of each lamp was:

a. Corrected ____________________

b. Uncorrected ____________________

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 2B - 3**	**Revised 07/2014 UEENEEG033A**

Twin 18 Watt Fluorescent Lamp Connections

Objective

To connect up a typical single twin 18 watt fluorescent lamp circuit and observe its operation.

Equipment

Twin 18 watt fluorescent project board.
Multimeter.
0-100 watt wattmeter.
0-1 A a.c. ammeter
Connecting leads
Single phase lead.
Manufacturer's data relating to fluorescent lamps.

Procedure

Danger Tag Procedure Required

1. Draw a circuit diagram of a twin 18 watt fluorescent lamp circuit connected to a 240 volt a.c. supply. Include instruments to measure the line voltage and line current.

2. Connect the project in accordance with your circuit diagram.
3. Check the circuit for shorts with the multimeter.
4. Have the circuit checked by your Lecturer
5. Energise the circuit and test for correct operation.
6. Measure the line voltage and line current and record the readings in the results table.
7. Switch the circuit off and remove the plug from the outlet.
8. Have your results checked by your Lecturer.
9. Disconnect your circuit and return all of the equipment to its proper place.

<u>Results Table</u>

	Voltage
Line Voltage	
Balast	
Tube 1	
Starter 1	
Tube 2	
Starter 2	
Capacitor	
Filament	

Line Current	

Questions

1. Why does the sum of the voltages across the tubes and the ballast add up to more than the line voltage?

   ----

2. When the lamps are working, what effect would it have on their operation when the starters are safely removed from the circuit?

   ----

3. Why are twin 18W luminaires used in preference used in preference to single 36W luminaires

   ----

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 2 Part C**	**Revised 07/2014 UEENEEG033A**

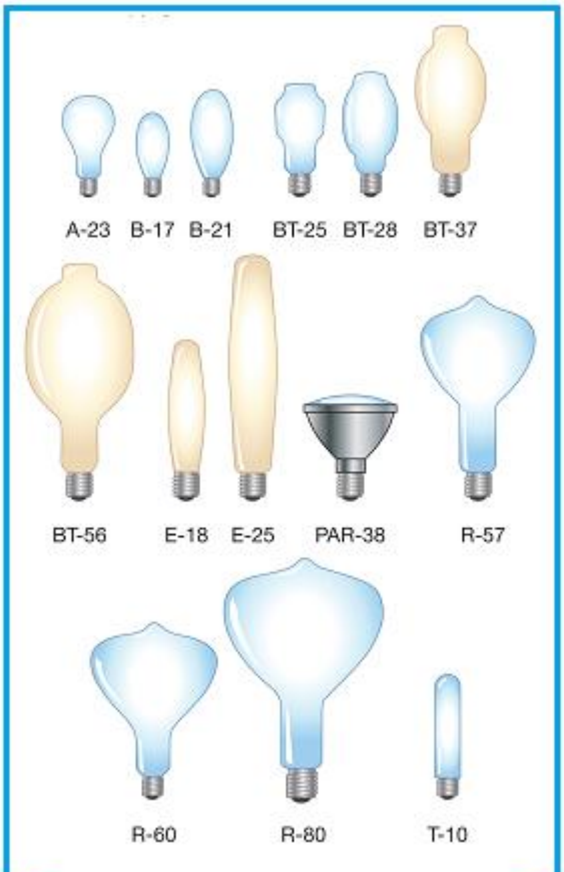
High intensity discharge lighting:

Topic 13	Required skills and knowledge:
	• types of high intensity discharge lamps. • expected lamp life, colour rendering and efficacy for typical types of high intensity discharge lamps. • operation of high intensity discharge luminaires including their control equipment. • Australian Standard and local requirements for high intensity discharge lighting. • methods for satisfying Australian Standards and local supply authority requirements regarding high intensity discharge lighting. • LED lighting and its applications. • Neon, Argon and Xenon lighting and their applications. comparison of incandescent, low intensity discharge, high intensity discharge, LED and other types of lighting.

Student Activity	Done	
Read **Section 7.6 Gas discharge lamps** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 205 to 212		

Read **Section 7.6 Gas discharge lamps** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 205 to 212

There is a range of gas discharge lamps available for the various applications for domestic, commercial and industrial electrical installations.



These include:

- High pressure sodium vapour
- Low pressure sodium vapour
- Mercury vapour
- Self- ballasting mercury vapour
- Metal halide

All of these lamps are available in a range of shapes and wattages.
The ancillary equipment required for each lamp can vary from a ballast or choke and power factor correction capacitor to ignitors for some high pressure sodium vapour and metal halide lamps.

It is important to refer to the manufacturer's instructions and match the lamps to the associated control gear when replacing parts.

A high pressure sodium lamp may require an ignitor to suit or may come with an internal ignitor.
This is identified in the part number as show here with this Osram lamp:

- VIALOX NAV-E/I High-pressure sodium vapour lamps with internal igniter

Each manufacturer supplies a range of technical information with each lamp.
This includes but is not restricted to:
Wattage, Voltage and Current are the basics for matching of ancillary equipment.
Efficacy, Rated luminous flux, Colour rendering index Ra, Colour temperature and the Spectral energy distribution graph are required for use with the standards when designing a lighting system.
Other information that can be important is dimensions, weights, base type and burning positions.

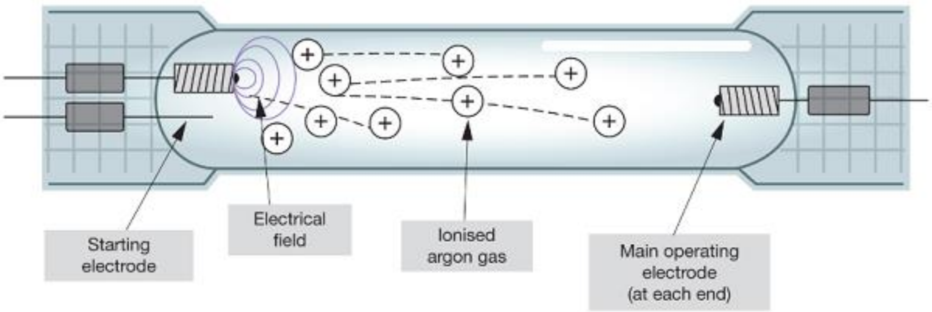
High Intensity Discharge Lamps

Principle of Operation

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.

1. The column of gas in the discharge tube is an insulator until the arc is initiated and ionisation occurs.

2. In the ionisation process, the gas atoms assume an excited state, in which some electrons change energy levels and, in so doing, radiate energy of particular wavelengths peculiar to the gas employed.



3. Once ionisation of the gas takes place, the current density increases rapidly and, in effect, the tube now becomes a short circuit.

4. To protect the lamp, which is now a short circuit, a ballast is incorporated in the circuit. The ballast has two functions: to limit the current to a predetermined value, and to provide the necessary starting voltage across the discharge tube. A ballast consumes power, which must be added to the lamp wattage when calculating circuit currents.

Basic operation of a discharge lamp

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.

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. Pressure of gas.
c. Fluorescent powder used.

Limitation of Current

As soon as the discharge in the tube has started, o_ne 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 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:

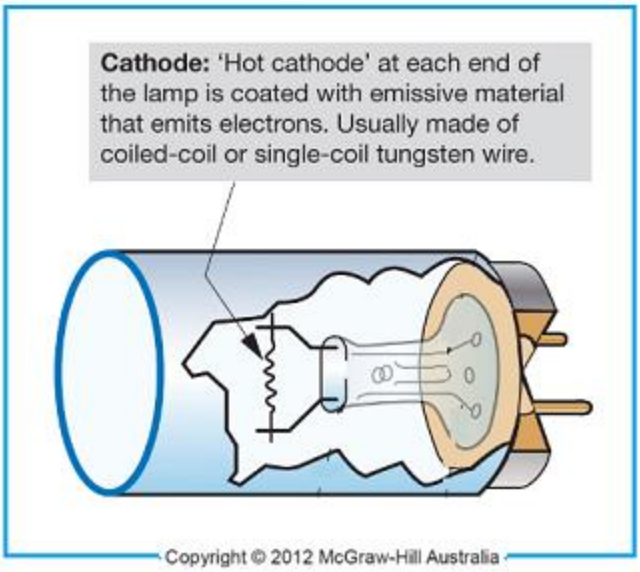
it will also provide the high voltage required in some circuits.

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.

Hot and Cold Cathodes {Electrodes)

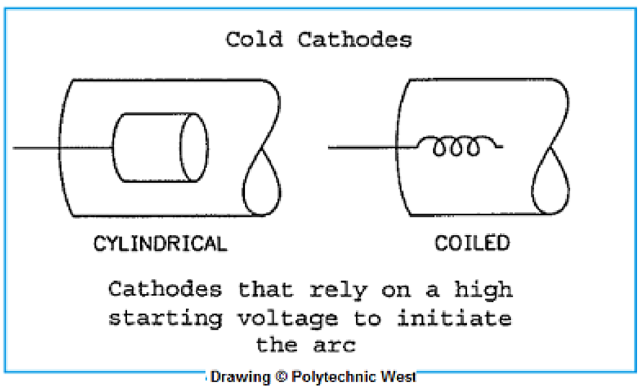
To initiate electron emission two basic methods are used:

a. Hot Cathode: the electrodes are pre-heated to an electron- emissive state (electrons are boiled off the electrodes).



b. Cold Cathode: where brute force (high voltage) is used to splutter electrons free of the electrodes.

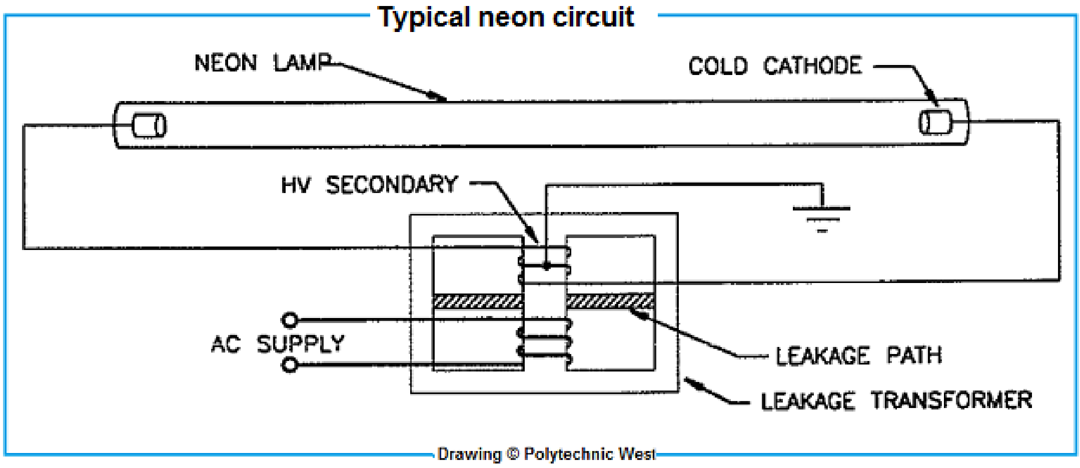
These cathodes rely on a high starting voltage to initiate the arc.



Types of Discharge Lighting

Neon Lighting (Cold Cathode)

With 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.

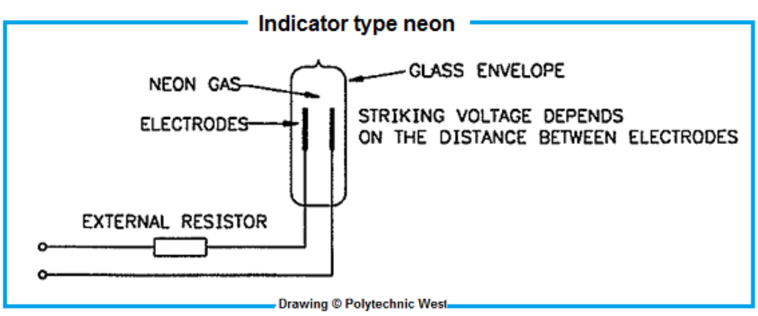
Neon lighting is very seldom used for general lighting due to its colour output, but because the neon tube can be started and stopped almost instantaneously it is frequently used for rapidly flashing signs, stroboscopes or engine timing lights.

Neon Indicating Lamps

The short distance between the electrodes, enables a relatively low voltage to start the discharge. The current is limited by a resistor fitted externally or in the base of the lamp.

Common types are:

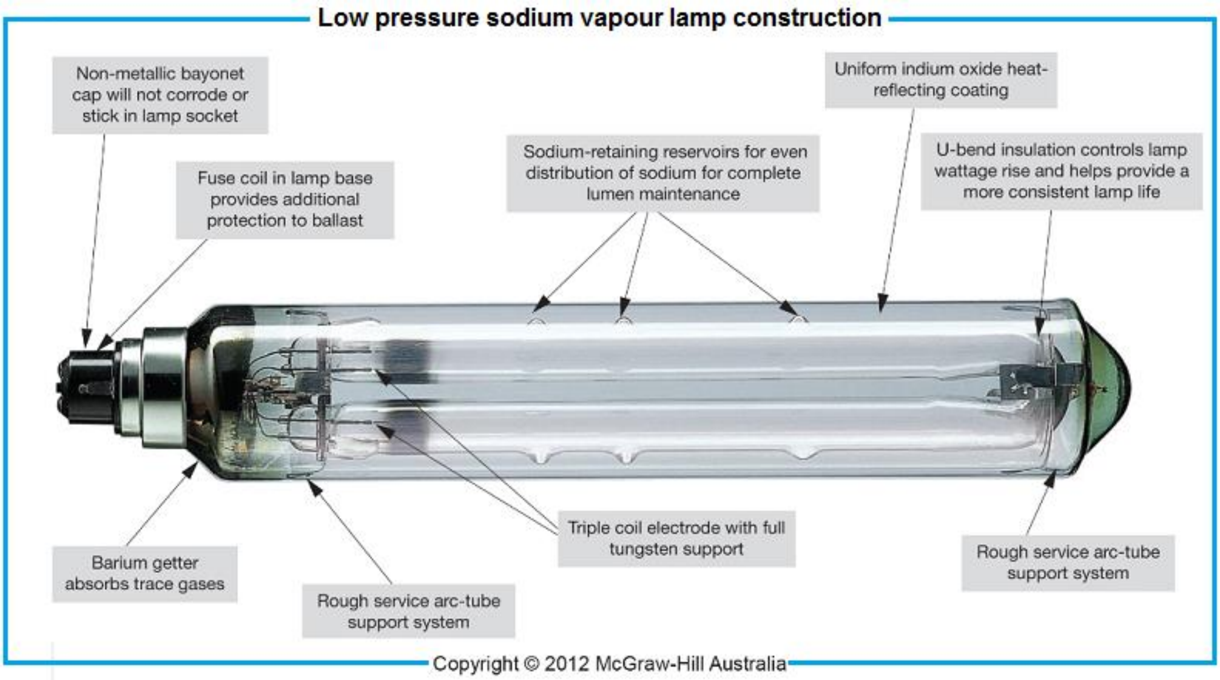
a. 5 W Beehive or Disc
b. 0.5 W Indicator
c. Phase pencil type



Sodium Vapour Lamps

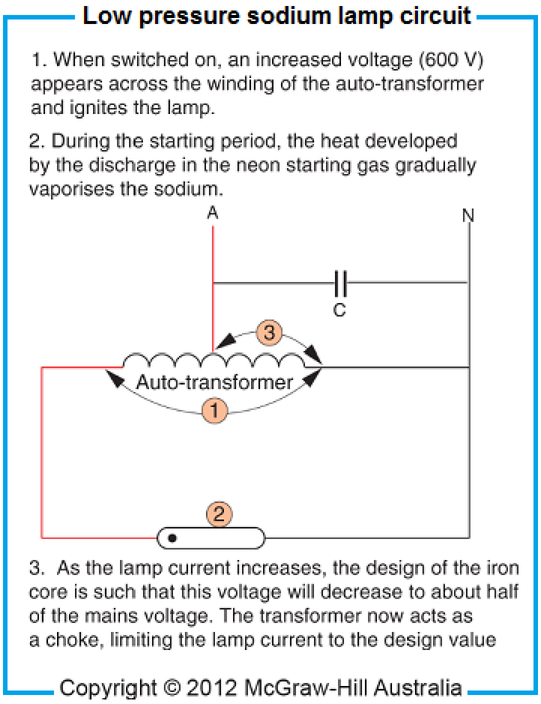
There are several different types of sodium vapour lamps, the main difference being the pressure at which the luminous discharge occurs. The following paragraphs give the general principles of the lamps.

Low pressure sodium lamps



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 nanometres.

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.

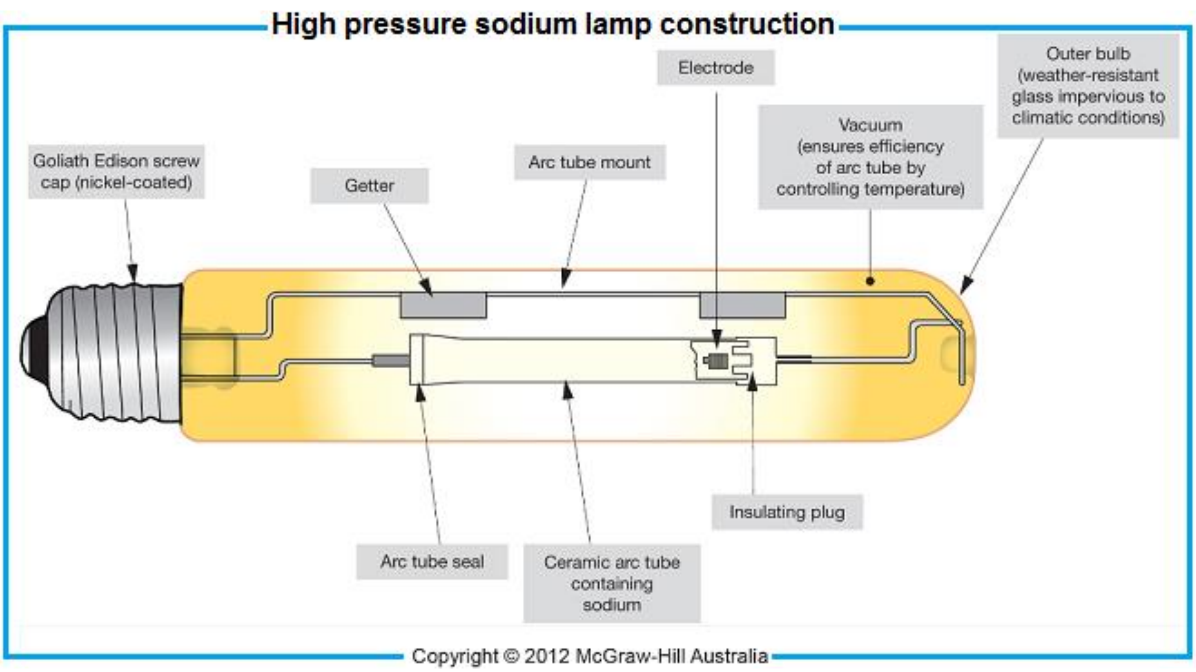


Applications

Since the light output is monochromatic, it is able to 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 has enabled Sodium lamps to operate at a higher pressure and temperature, resulting in a more acceptable colour distribution in light output (whiter light).

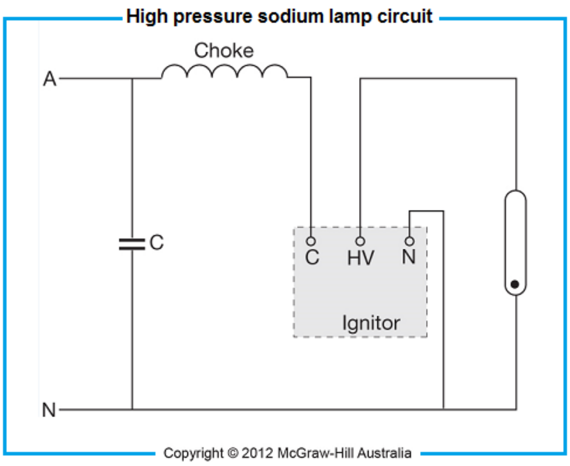


Note: The arc tube is made of sintered aluminium oxide to withstand the intense chemical activity of sodium vapour at high temperature and pressure.

Operation

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.

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.

Applications

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.

Mercury Vapour Lamps

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).

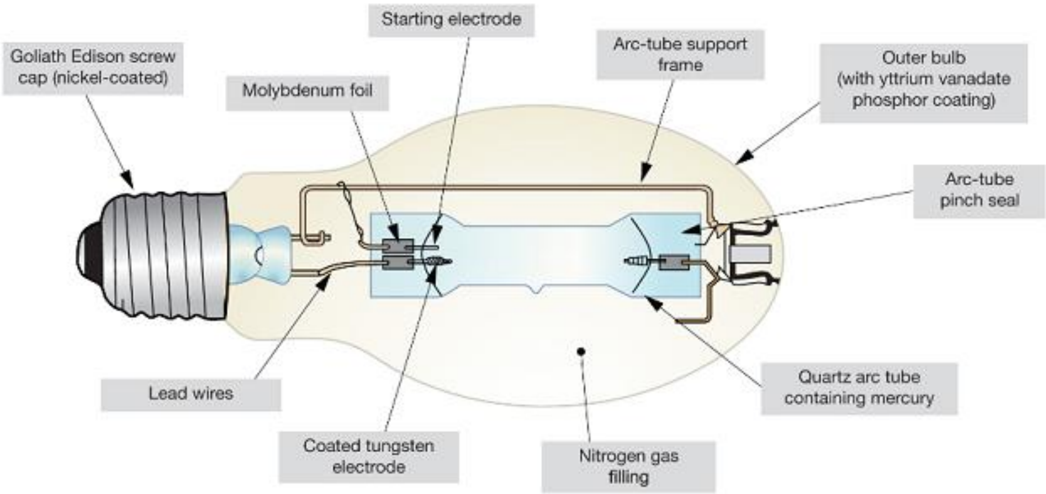
Operation

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, resulting in an increase in 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

Normally, this lamp can only be operated in the vertical position, because in the horizontal position, convection currents in the gas would cause the arc to bow upwards, damaging the tube. A special magnetic deflector can be fitted to the lamp to prevent this and enable it to be operated in the horizontal position

Mercury vapour lamp

The outer bulb is filled with nitrogen, an inert gas. This maintains internal electrical stability to eliminate flashovers, provides thermal insulation of the arc tube and protects the metal parts from oxidisation. The quartz arc tube contains a precise amount of high-purity mercury and a starting gas, argon.



When the lighting circuit is energised, the starting voltage is impressed across the gap between the main electrode and the starting electrode. This voltage creates an argon arc between the starting electrode and the main electrode, and current is limited to a very low level by the starting resistor. The heat from this argon arc causes the mercury to begin to vaporise, and the resistance between the main electrodes drops. When resistance drops to a point where the voltage available from the ballast can establish an arc, the main arc strikes, vaporising more mercury. The resistance of the starting circuit is now high compared with that across the main gap, and the starting arc ceases. The main arc current is limited by a series-connected external ballast

High Pressure MV Lamps

By using a special grade of quartz glass for the inner tube, it is possible to operate the lamp at a considerably higher pressure. The lamp is basically the same as the medium pressure unit, except that the discharge tube is shorter and the glass envelope is frosted to diffuse the light and reduce the glare.

The advantages of a high pressure lamp are:

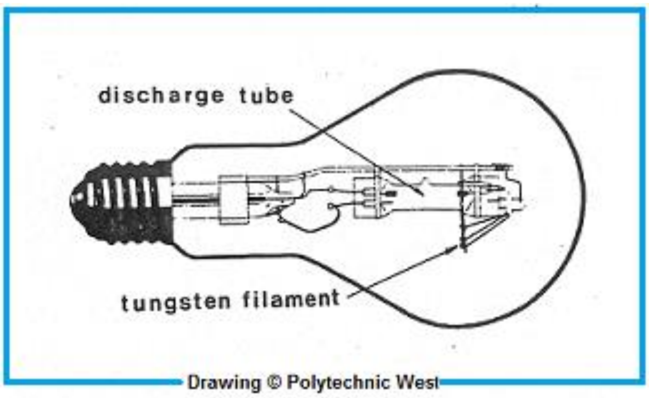
a. Less time taken to reach full luminous output.
b. Time between re-strikes is reduced.
c. Lamp can be burned in any position.
d. Lamp can be used in standard fittings.
e. Higher pressure operation produces some red rays - better colour rendering.

When the interior surface of the glass is coated with a fluorescent phosphor, which converts ultra violet radiation from the discharge into visible light, improved colour rendering is obtained. This is called a 'Colour Corrected Lamp'. Most modern MV lamps are colour corrected, and have efficacies between 50 to 60 lumens per watt.

Self Ballasting (Mercury Tungsten Lamps)

As the name suggests this type of lamp does not require an 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.



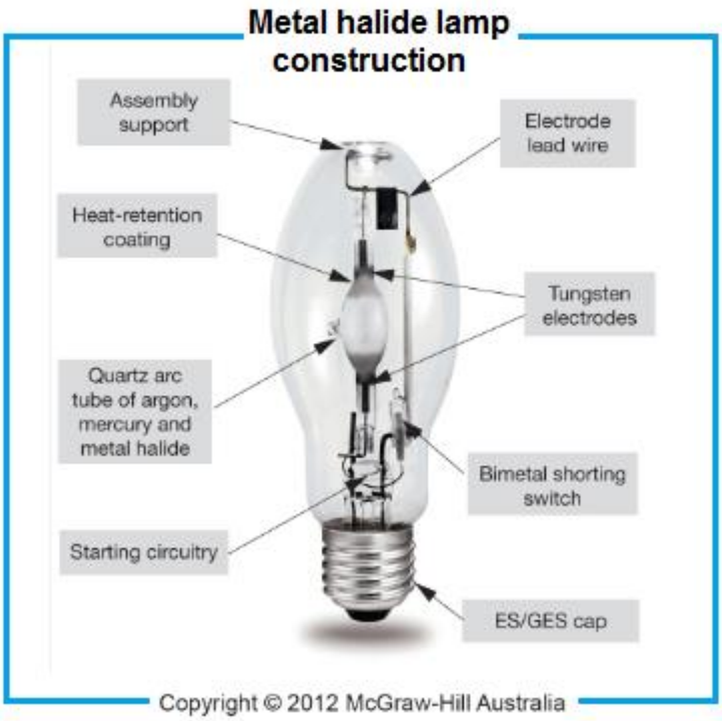
Lamps are available with ES or BC cap and can be used as a direct replacement for normal incandescent lamps giving higher light output and six times the life.

Mercury tungsten lamps are designed to operate in the cap up position up to about 30 degrees from vertical. Their efficacies are between 16 to 28 lumens per watt, and their rated life is 8000 hours.

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.

Metal Halide Lamps

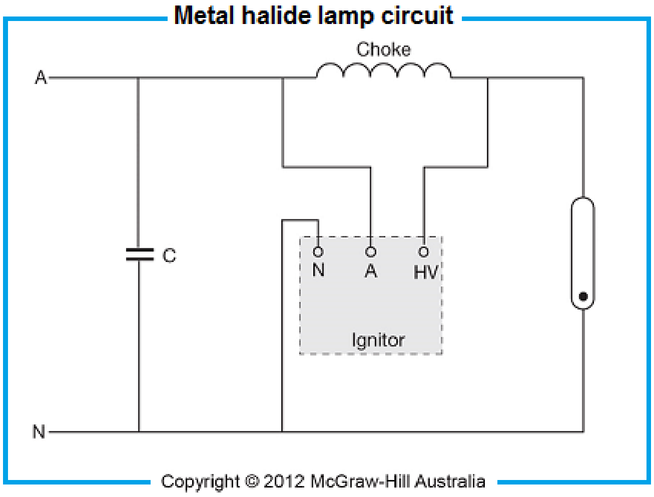
These lamps operate on the same principle as all gas discharge lamps, and are basically high pressure mercury vapour lamps with metal halide additives (sodium, thallium and indium iodides} to the quartz arc tube.



The special additives in the arc has 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.

The elliptical type has a diffusing coating on the outer glass envelope and is very similar in appearance to high pressure MV lamps.

They are normally designed to operate in. the horizontal position within 30 degrees in open type luminaires, whereas. The tubular type have a clear outer glass envelope which is enclosed in a suitable luminaire to provide an accurately controlled powerful beam of light. The 'linear type' consists of a quartz arc tube which must be enclosed in the correct fitting. Precautions. that should be observed with this type are; that they must be in the horizontal burning position, the lamp must not be touched with the bare hands, and the base lamp should not be viewed with the naked eye due to its UV content which is normally filtered out by the lamp's luminaire.



Metal halide lamps have an efficacy of 70-100 lumens per watt with a run up time of 10-15 minutes and a re-striking 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.

Starting Requirements

The starting conditions for mercury vapour lamps no longer apply to the starting requirements for metal halide lamps due to the presence of the free iodine additive. During the run up time high re-ignition lamp voltage peaks can occur and lamps will extinguish if insufficient voltage is obtainable.

The majority of circuits use a solid state igniter in conjunction with a conventional MV lamp ballast. The special igniter provides a high voltage pulse every cycle for positive and reliable ignition.

Igniters are not necessarily an integral part of the lamps circuit and can be positioned in any part of the overall circuit. The only limitation placed on its position is the capacitance of the cable used. Do not use MIMS cable.

Cable Length Limitations

The cable length between the lamp and ballast is limited by the value of capacitance between it and all conductors bonded together plus the value of capacitance to earth. A typical value of capacitance is 20 000 pF.

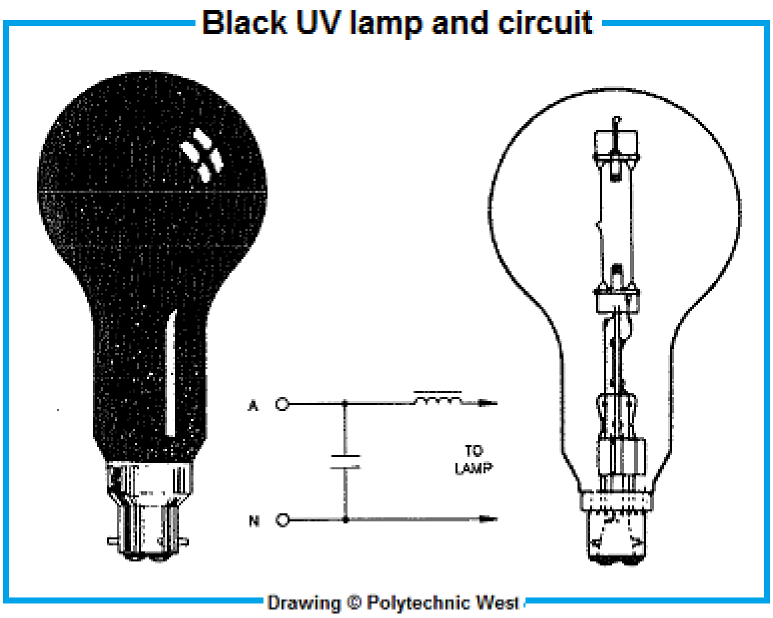
Some early type lamps use an internal starter switch coupled to a high reactance transformer winding to provide the peak, voltage required for striking.

The excellent colour rendering and high efficacy of metal halide lamps make them ideal lighting units where colour is of primary importance; indoors for shops, supermarkets, stores, sports halls and swimming pools; outdoors for stadium floodlighting for football and trotting. Metal halide lamps have proved suitable light sources for use with colour television cameras. The only restriction on the acceptance of these lamps is their high initial cost and efficacy loss over their life span.

Black UV Lamps

Black ultra violet lamps are basically mercury vapour lamps. The arc tube is enclosed in an outer envelope of black woods glass which absorbs virtually all the radiation from the arc tube other than that in long wave

Note: UV lamps must be used with the correct control gear. Their bases are normally of a special configuration, e.g. 3 pin BC or ES.



Several other varieties of UV lamps are available each with their own particular wavelength of UV radiation required for specific applications.

Applications

Black UV lamps are used as a source of UV radiation to excite fluorescence in suitable materials. They have a number of applications such as analysis and detection in the chemical and textile industries, in food production, mineralogy, banking, criminology, medicine and for special effects in the entertainment field.

The rays emitted from a source of UV radiation are extremely harmful to the eyes when viewed directly. Care should be taken with all types of UV lamps and prolonged exposure to them should be avoided.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 2C -1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. What item of control equipment is required with most illuminating lamps which operate on the "gas discharge" principle?

2. What potentially dangerous situation can arise if a single gas discharge lamp is used over a rotating machine?

3. What is the main factor which determines the colour at which a "neon" lamp operates?

4. What type of "cathode" does a neon lamp normally have?

5. What type of control equipment is usually installed with a neon illuminating lamp?

6. What is the characteristic colour given off by a low pressure sodium vapour lamp when operating at full brilliance?

7. What precaution must be taken when disposing of sodium vapour lamps?

8. What is the characteristic colour given off by a mercury vapour lamp when it is operating at full brilliance?

9. Why is it dangerous to operate a mercury vapour lamp if the outer glass envelope is broken?

10. What type of mercury vapour lamp can be installed without any additional control equipment?

11. What three items of control equipment are usually required with high pressure mercury vapour or metal halide lamps?

12. What is the only type of illuminating lamp which can be operated on DC without any control equipment?

13. What are the two main methods of producing light electrically?

14. Identify two possible causes of insulation failure in a luminaire.

15. Why is it essential to perform an insulation resistance test on electrical equipment before connecting them to the supply? State the test voltage required and minimum allowable insulation resistance value.

16. If the capacitor is disconnected in any discharge lighting circuit, what would be the most likely outcome in terms of current and power factor?

17. Apart from isolating the supply, what is the essential safety procedure that must be followed before working on large banks of discharge lighting?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity 2C -2**	**Revised 07/2014 UEENEEG033A**

Low Pressure Sodium Vapour Lamp Characteristics

Objective

To connect up a typical low pressure sodium vapour lamp and observe its operation.

Equipment

A low pressure sodium vapour lamp (35 watts or similar).
Circuit diagram as provided by the manufacturer.
Multimeter.
0 -100 watt wattmeter.
0 -1A a.c. ammeter
Connecting leads.
Single phase lead.
Stop-watch.
Manufacturer's data relating to the sodium vapour lamp.

Procedure

Danger Tag Procedure Required

1. Copy the circuit diagram supplied by the manufacturer. Modify the circuit to include instruments to measure the line voltage, line current and power.

2. Connect the project in accordance with your circuit diagram.

3. Check the circuit for shorts with the multimeter.

4. Have the circuit checked by your Lecturer

5. Energise the circuit and test for correct operation. Observe the behaviour of the lamp and the measuring instruments over a 5 minute period (do not look directly at the lamp for more than a few seconds).

6. Measure and record the line voltage, line current and the power after the 5 minutes has elapsed.

Line Voltage: ____

Line Current: ____

Power: ____

8. Switch the circuit off and remove the plug from the outlet.

9. Have your results checked by your Lecturer.

10. Disconnect your circuit and return all of the equipment to its proper place.

<u>Questions</u>

1. How did the behaviour of the lamp vary from the behaviour of a standard 40 watt gas-filled incandescent lamp on 240 volts?

----

2. What colour was the light emitted by the lamp when it was first switched on?

----

3. What colour was the light emitted by the lamp after it had been on for 5 minutes?

----

4. What are the permissible mounting positions for a low pressure sodium vapour lamp according to the manufacturer?

----

5. Give two suitable applications for the lamp used in this project.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity 2C - 3**	**Revised 07/2014 UEENEEG033A**

High Pressure Sodium Vapour Lamp Characteristics

Objective

To connect up a typical high pressure sodium vapour lamp and observe its operation.

Equipment

A high pressure sodium vapour lamp (35 watts or similar).
Circuit diagram as provided by the manufacturer.
Multimeter.
0 -100 watt wattmeter.
0 -1A a.c. ammeter
Connecting leads.
Single phase lead.
Stop-watch.
Manufacturer's data relating to the sodium vapour lamp.

Procedure

Danger Tag Procedure Required

1. Copy the circuit diagram supplied by the manufacturer. Modify the circuit to include instruments to measure the line voltage, line current and power.

2. Connect the project in accordance with your circuit diagram.

3. Check the circuit for shorts with the multimeter.

4. Have the circuit checked by your Lecturer

5. Energise the circuit and test for correct operation. Observe the behaviour of the lamp and the measuring instruments over a 5 minute period (do not look directly at the lamp for more than a few seconds).

6. Measure and record the line voltage, line current and the power after the 5 minutes has elapsed.

Line Voltage: ____

Line Current: ____

Power: ____

8. Switch the circuit off and remove the plug from the outlet.

9. Have your results checked by your Lecturer.

10. Disconnect your circuit and return all of the equipment to its proper place.

Questions

1. How did the behaviour of the lamp vary from the behaviour of a standard 40 watt gas-filled incandescent lamp on 240 volts?

----

2. What colour was the light emitted by the lamp when it was first switched on?

----

3. What colour was the light emitted by the lamp after it had been on for 5 minutes?

----

4. What are the permissible mounting positions for a high pressure sodium vapour lamp according to the manufacturer?

----

5. Give two suitable applications for the lamp used in this project.

Government of Western Australia North Metropolitan TAFE	Solve problems in single and three phase low voltage electrical apparatus and circuits	Activity 2C - 4	Revised 07/2014 UEENEEG033A

High Pressure Mercury Vapour Lamp Characteristics

Objective

To connect up a typical high pressure mercury vapour lamp and observe its operation.

Equipment

A high pressure mercury vapour lamp (35 watts or similar).
Circuit diagram as provided by the manufacturer.
Multimeter.
0 -100 watt wattmeter.
0 -1A a.c. ammeter
Connecting leads.
Single phase lead.
Stop-watch.
Manufacturer's data relating to the mercury vapour lamp.

Procedure

Danger Tag Procedure Required

1. Copy the circuit diagram supplied by the manufacturer. Modify the circuit to include instruments to measure the line voltage, line current and power.

2. Connect the project in accordance with your circuit diagram.

3. Check the circuit for shorts with the multimeter.

4. Have the circuit checked by your Lecturer

5. Energise the circuit and test for correct operation. Observe the behaviour of the lamp and the measuring instruments over a 5 minute period (do not look directly at the lamp for more than a few seconds).

6. Measure and record the line voltage, line current and the power after the 5 minutes has elapsed.

Line Voltage: ________________________________

Line Current: ________________________________

Power: ________________________________

8. Switch the circuit off and remove the plug from the outlet.

9. Have your results checked by your Lecturer.

10. Disconnect your circuit and return all of the equipment to its proper place.

<u>Questions</u>

1. How did the behaviour of the lamp vary from the behaviour of a standard 40 watt gas-filled incandescent lamp on 240 volts?

   ----

2. What colour was the light emitted by the lamp when it was first switched on?

   ----

3. What colour was the light emitted by the lamp after it had been on for 5 minutes?

   ----

4. What are the permissible mounting positions for a high pressure mercury vapour lamp according to the manufacturer?

   ----

5. Give two suitable applications for the lamp used in this project.

   ----

6. What type of lamp holder was required for the lamp used in this project.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity 2C - 5**	**Revised 07/2014 UEENEEG033A**

Metal Halide Lamp Characteristics

Objective

To connect up a typical metal Halide lamp and observe its operation.

Equipment

A metal halide (35 watts or similar).
Circuit diagram as provided by the manufacturer.
Multimeter.
0 -100 watt wattmeter.
0 -1A a.c. ammeter
Connecting leads.
Single phase lead.
Stop-watch.
Manufacturer's data relating to the metal halide lamp.

Procedure

Danger Tag Procedure Required

1. Copy the circuit diagram supplied by the manufacturer. Modify the circuit to include instruments to measure the line voltage, line current and power.

2. Connect the project in accordance with your circuit diagram.

3. Check the circuit for shorts with the multimeter.

4. Have the circuit checked by your Lecturer

5. Energise the circuit and test for correct operation. Observe the behaviour of the lamp and the measuring instruments over a 5 minute period (do not

look directly at the lamp for more than a few seconds).

6. Measure and record the line voltage, line current and the power after the 5 minutes has elapsed.

Line Voltage: ___________________________________

Line Current: ___________________________________

Power: ___________________________________

8. Switch the circuit off and remove the plug from the outlet.

9. Have your results checked by your Lecturer.

10. Disconnect your circuit and return all of the equipment to its proper place.

<u>Questions</u>

1. How did the behaviour of the lamp vary from the behaviour of a standard 40 watt gas-filled incandescent lamp on 240 volts?

   ----

2. What colour was the light emitted by the lamp when it was first switched on?

   ----

3. What colour was the light emitted by the lamp after it had been on for 5 minutes?

   ----

4. What are the permissible mounting positions for a metal halide lamp according to the manufacturer?

   ----

5. Give two suitable applications for the lamp used in this project.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 2 Part D**	**Revised 07/2014 UEENEEG033A**

Emergency and evacuation lighting and lighting control:

Topic 10	**Required skills and knowledge:**
	• factors and requirements of emergency and evacuation lighting concerning illumination levels, luminaire positioning and operating period. • characteristics of maintained, non maintained and sustained emergency lighting systems. • arrangement of batteries in point and central bank emergency lighting supply systems. • lighting control methods

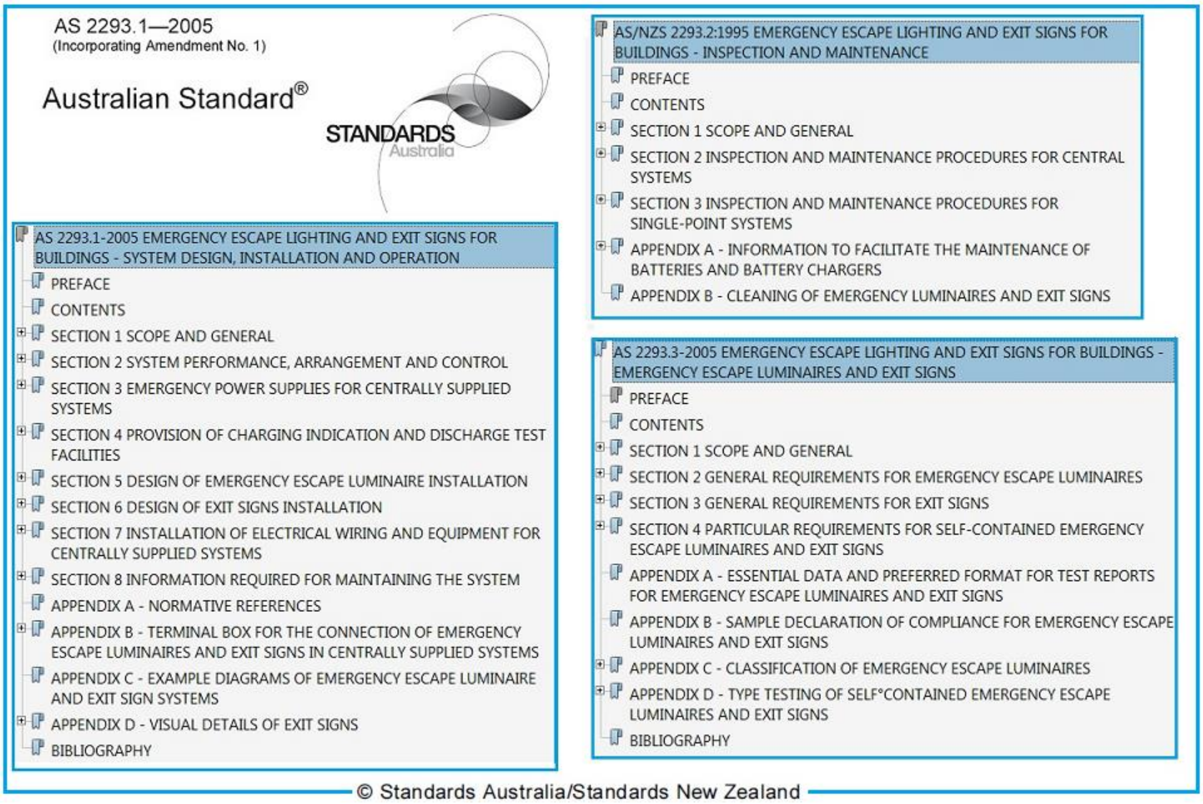
Student Activity	**Done**	
Read **Section 2.4 Evacuation and fire control** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 54 to 57		
Read **Part 4 Lighting** of Health (Public Buildings) Regulations 1992’		

Read **Section 2.4 Evacuation and fire control** in Electrical Wiring Practice (7th ed.) Vol.2 Pages 54 to 57

The Building Code of Australia (BCA) requires that commercial and public buildings meet the requirements set out in the AS2293 set of Australian standards for exit and emergency lighting.

Exit lighting is required to be illuminated at all times and emergency lighting is to operate automatically by battery back up to provide sufficient illumination for people to evacuate buildings if required in the event of a power failure or emergency.

Australian standard series 2293 provides guidance on the requirements for the installation, inspection and maintenance of emergency lighting and exit signs.



In Western Australia the electrician must be aware of the requirements of the ‘Health (Public Buildings) Regulations 1992’. These regulations provide the general lighting requirements for public buildings including emergency and evacuation lighting.

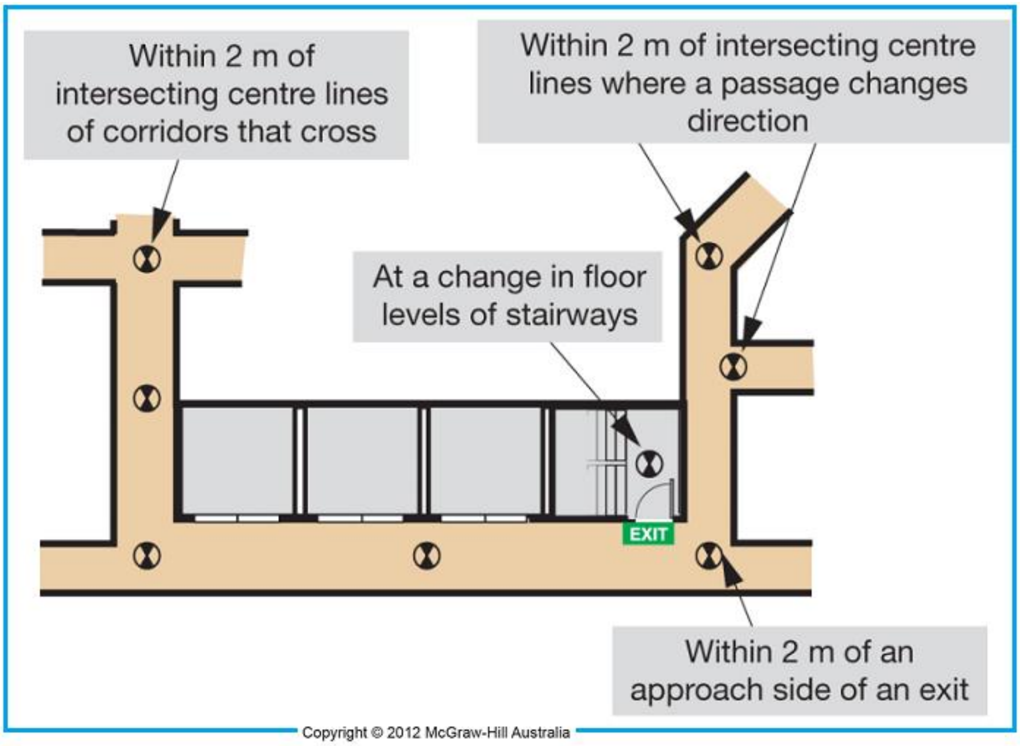
This document is availalable free on the State Law Publisher website.

For emergency lighting these regulations require that installation and maintenance to be in accordance with the AS2293 series of Australian standards.

State Law Publisher
https://www.slp.wa.gov.au

Luminaire positioning

Section 5 of AS2293.1:2005 covers the design of emergency escape luminaire installation.



Illumination levels

Clause 5.4.2.3 of AS2293.1:2005 requires that emergency escape luminaires be installed throughout the designated area to ensure that the calculated horizontal illuminance at floor level is not less than 0.2 lx.

Duration of operation of emergency power
Clause 2.2 of AS2293.1:2005 requires that the operation on emergency power of every escape luminaire or exit sign be 90 minutes. Although at commissioning, to allow for depreciation of capacity over time, 120 minutes of operation time is required to be verified.

Battery arrangement and installation
Clause 3.3 of AS2293.1:2005 provide the requirements for the type of batteries permissible and the installation requirements.
Batteries are to be installed in accordance with AS3011.1 or AS3011.2 with the following extra requirements:

- Materials for the enclosure must be resistant to the corrosive effects of the electrolyte.
- DC reticulation systems shall be unearthed with a 10 mA earth fault detection system.
- Connections to batteries are to be made with bolted lugs.
- Overcurrent protection to prevent discharging into the charger.
- A rating plate with required information.

Section 6 of AS2293.1:2005 covers the design of exit sign installation.

The new international pictogram depicts a running person in the direction of the exit and is coloured green on white.

Wherever exit signs are displayed the path and exit must be kept unobstructed for emergency purposes.

Power for emergency lighting come under two systems:

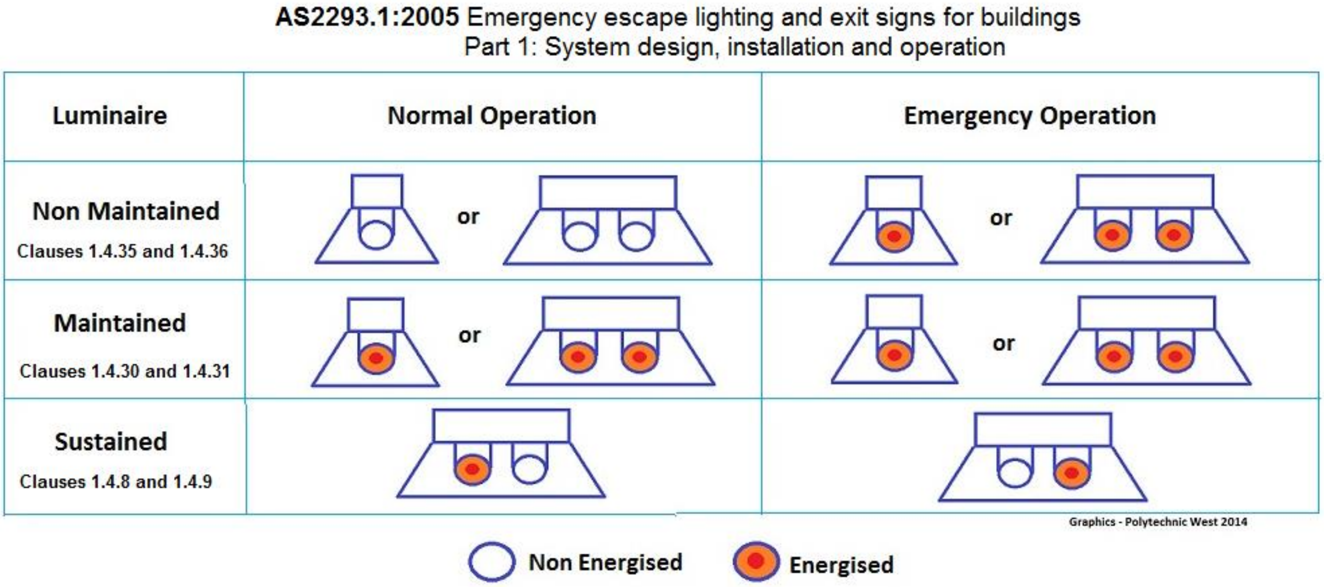
- Single point / Self contained
- Central battery

Section 7 of AS2293.1:2005 covers the installation of electrical wiring and equipment for centrally supplied system.

The single point system is the most common and there are three basic types of luminaires.

- Non-Maintained
- Maintained
- Sustained

These are mains connected luminaires with batteries that are constantly on charge for back up. Illumination of the lamps occur under emergency conditions when there is a failure of the mains power supply.



Non maintained fittings have lamps that are not illuminated under normal operation.
Maintained fittings have lamps that are illuminated under normal operation.
Sustained fittings have two lamps. One lamp is illuminated under normal operation and the second is illuminated under emergency operation.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 2D -1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. Describe the three purposes of emergency lighting.

2. Name two modes of operation which are applicable to the installation of emergency lighting systems such as self-contained exit lights.

3. State the Australian Standard that specifies requirements for exit signs and emergency escape lighting in buildings.

4. What is the minimum illuminance level required for emergency lighting?

5. What is the minimum time period that that an emergency light must maintain illumination as per the AS2293?

6. What are the advantages of using a monitored emergency lighting system?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 2E - 1**	**Revised 07/2014** **UEENEEG033A**

Complete the review questions for Chapter 7 in Electrical Wiring Practice (7th edition) Vol.2 on pages 225 to 226.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 3 Part A**	**Revised 07/2014 UEENEEG033A**

Fire protection – residential fire and smoke alarms encompassing:

Topic 9	**Required skills and knowledge:**
	• regulations and standards requirements regarding residential fire and smoke alarms. • locations for residential fire and smoke alarms. • wiring methods for residential fire and smoke alarms. • operation of typical residential fire and smoke alarms.

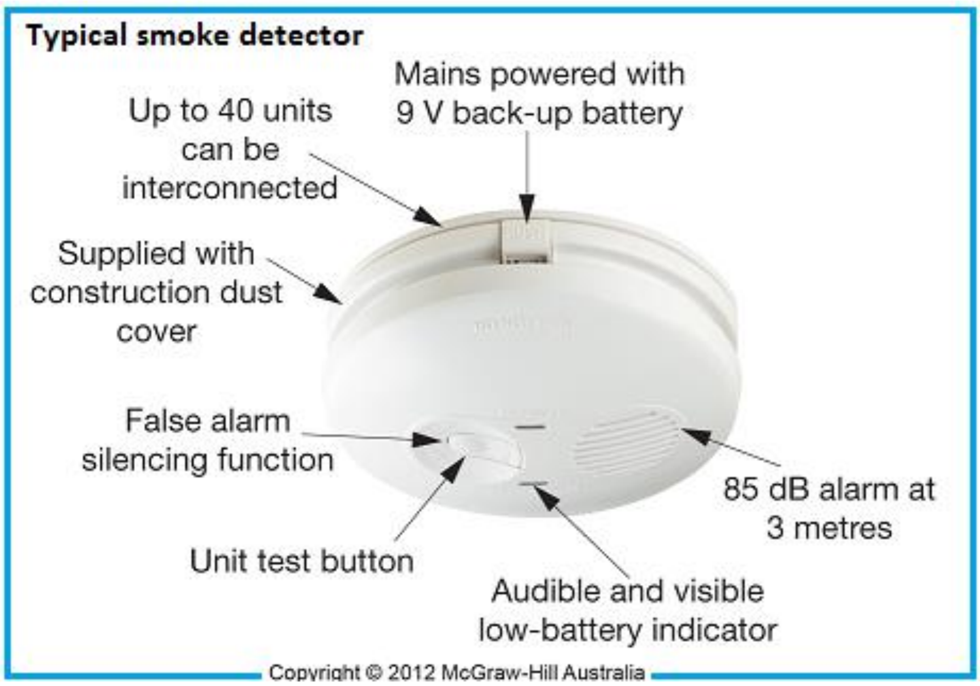
Student Activity Section	**Done**	
Read **Electrical installations for safety services:** Electrical Wiring Practice (7th ed.) Vol.2 Pages 45 - 63		
Read AS/NZS3000:2018 Clause 4.6 Smoke Alarms		

Fire and smoke alarms
There are a range of fire and smoke alarms available to suit a wide range of applications.

They include:
- Smoke detectors
- Heat detectors
- Gas detectors
- Flame detectors

Smoke detectors

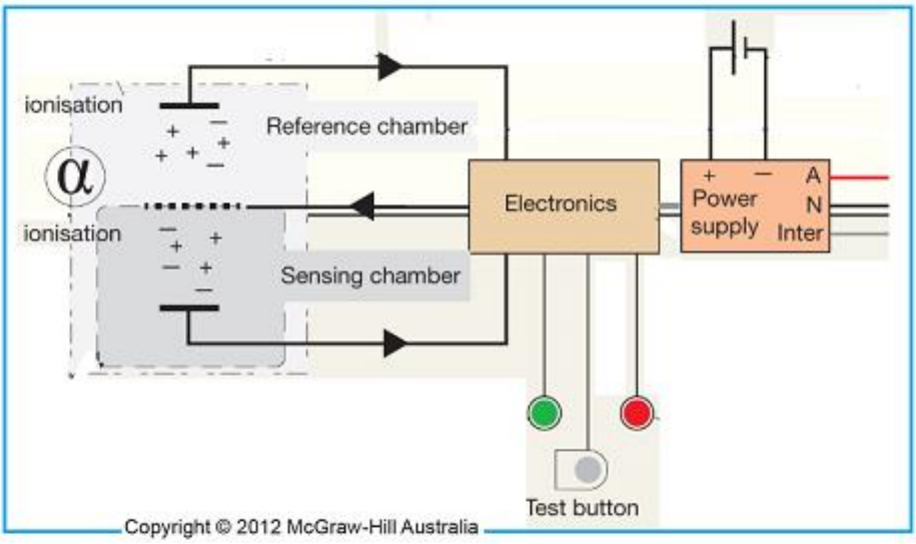
Smoke detectors for residential premises have audible alarms that are designed to wake sleeping residents.
They can be single point or interconnected.



The most common type of smoke detectors used for residential purposes are:

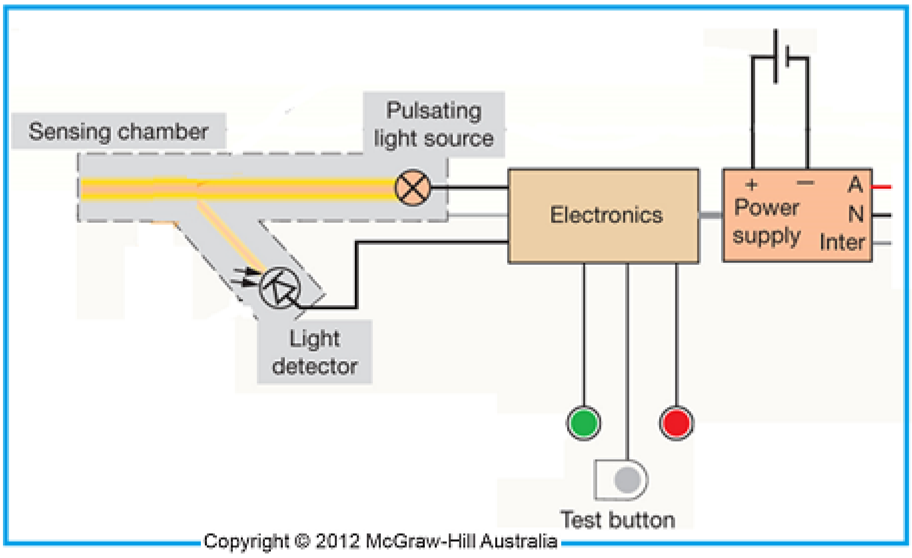
- Ionisation type smoke detector (no longer compliant to the AS 3786:2014 Standard)
- Photoelectric type smoke detector –
  All new smoke alarms that are installed into the residential properties from January 1, 2017, must be photoelectric and compliant with AS 3786-2014. This type of alarm has been proven to be more effective at detecting smouldering or slow-flaming fires common in the home environment.

The ionisation type smoke detector uses a small amount of radioactive material that emits positively charged particles to ionise the chamber.
A current flows between the two electrodes during normal operation. When smoke enters the chamber it reduces the current flow and the electronic circuit triggers the alarm.



The ionisation type smoke alarm is best suited to detecting a flaming, fast growing fire that produces a large amount of invisible charges particles and little smoke.

The photoelectric type of smoke detector uses a pulsating light source in the infra-red range usually from an LED. When smoke enters the chamber it deflects the light which is detected by the optoelectronic light detector and the alarm is triggered.



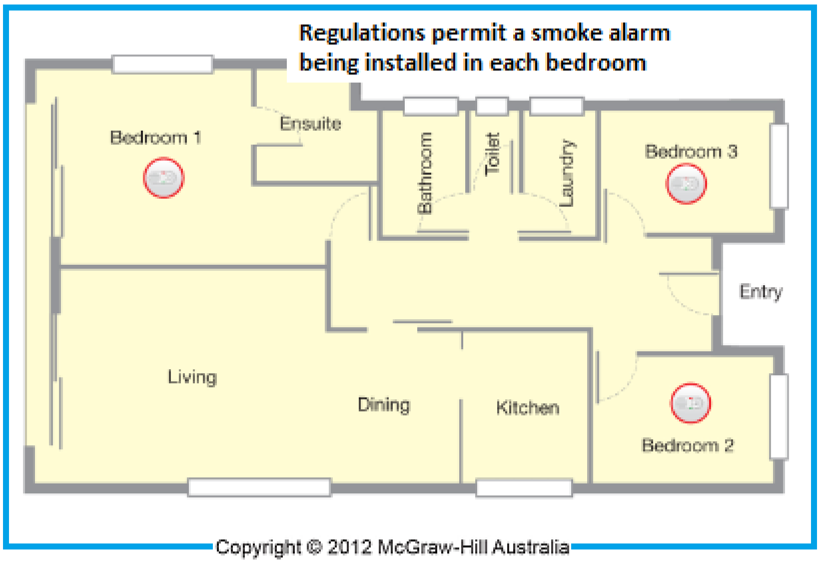
The photoelectric type smoke detector is best suited to smouldering fires that produce larger, denser and more visible smoke particles.

Clause 4.6 of the AS/NZS3000:2018 wiring rules allows mains powered smoke detectors to be connected to any lighting circuit or to an individual final sub circuit.

The national building code sets out the requirements for installing fire and smoke detectors in domestic residences that includes the requirements for the location and number of points.

The main focus when selecting a location for a smoke detector is the sleeping areas as they are designed to wake sleeping residents with an audible alarm.

The best protection for a residence is to have smoke detectors in every room except kitchens and garages or any area where particles that would trigger the alarm are normally present.
The detectors should be as close as possible to the centre of the room.



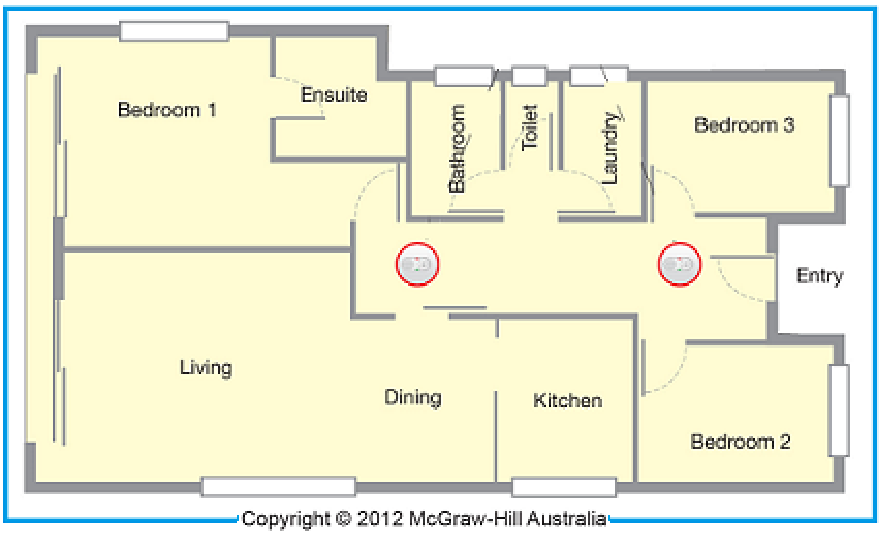
The minimum Building Code of Australia regulation is that a smoke alarm connected to the mains with a battery back-up be installed on or near the ceiling in any storey of a new residential dwelling.
Detectors should be placed in the bedrooms or in an area between the bedrooms and the rest of the dwelling.

The Regulations stipulate that is the owner's responsibility to ensure the smoke alarms fitted are:

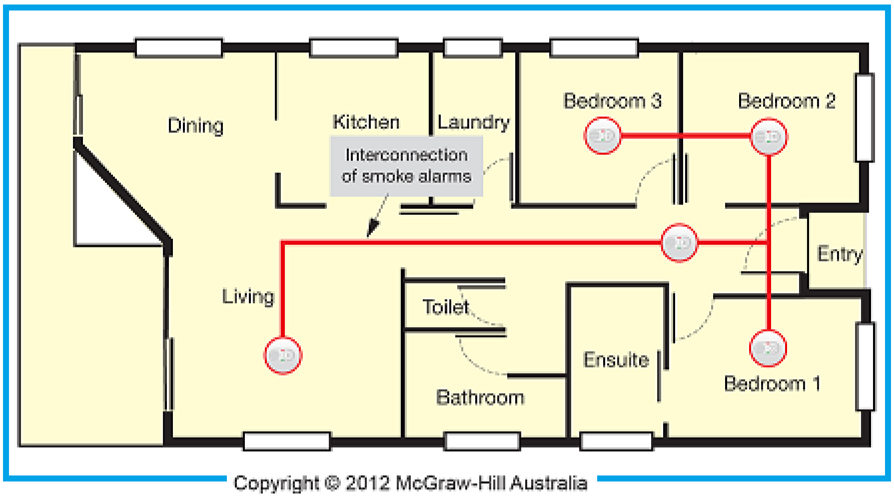
- No more than 10 years old.
- In working order.
- Permanently connected to the consumer mains power.
- In accordance with the relevant Building Code of Australia in effect at the time the alarms were installed.

Smoke alarms should be located outside the entrance to each bedroom or in a common area or hallway.

A distance of 900 mm from the doorway is recommended.



Interconnection of smoke alarms ensures that all areas receive a warning if a fire starts in any part of the dwelling.

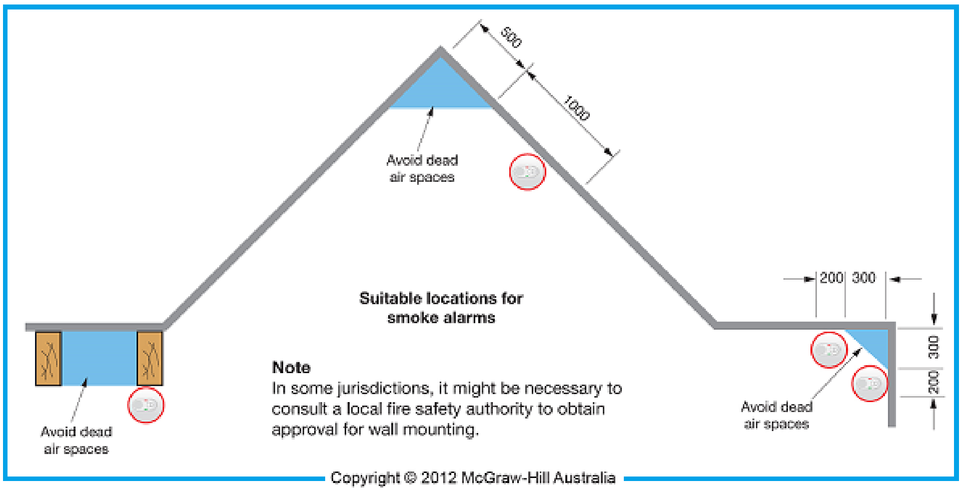


The Energy Bulletin number 67 from Energy Safety announced new changes to smoke alarm laws.

The new national smoke alarms laws featured in the Building Code of Australia, which came into effect on 1 May 2014, requires electrical contractors to interconnect smoke alarms in domestic installations, when more than one alarm is installed.

For dwellings under construction, smoke alarms must comply with approved plans and specifications that are associated with the building permit though WA does have a one year transition period.
Buildings that were constructed, or approved for construction before 1 May 2015 are not required to have smoke alarms interconnected.

It is important when locating smoke detectors to avoid dead air spaces where there is little or no air movement.



The department of fire and emergency services in WA (FESA) recommend the installation of the photoelectric type of smoke detector for residential dwellings. Research has shown that this type of smoke detector provides sufficient time for occupants to escape from smouldering and flaming fires.

Smoke alarms may detect smoke, heat and moisture created by common household activities such as burning toast or bathroom steam.

To reduce the likelihood of false alarms, a smoke alarm should not be located near:

- Cooking appliances
- Doorways to bathrooms and laundries
- Water heaters, space heaters or fireplaces
- Heating and cooling duct outlets, ceiling fans, doors and windows
- Fluorescent light fittings to avoid the effect of electrical noise or flickering lights
- Doorways and windows where barbecues and incinerators are located

General maintenance of the smoke alarm includes vacumming the unit to remove accumulated dust, cleaning with a damp cloth, pressing the test button once a month and replacing the battery at recommended intervals. Also the end of life of the unit should be observed and a replacement carried out. Most units are designed for ten years of service.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Work sheet 3A - 1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. There are two common types of smoke alarms that are used for residential dwellings. What are they and which one is supported by the Standard AS 3786:2014?

2. What AS/NZS300:2018 clause number relates to the installation of smoke and fire detectors?

3. What is the benefit of installing a mains powered smoke alarm in a lighting circuit of a domestic installation?

3. Indicate on this drawing where the minimum number of smoke detectors should be installed.

Copyright © 2012 McGraw-Hill Australia

4. Indicate on this drawing where the minimum number of smoke detectors should be installed.

Copyright © 2012 McGraw-Hill Australia

5. Which type of mains powered smoke alarm does FESA recommend for installation in residential dwellings in WA?

6. List three areas where smoke alarms should not be installed in a residential dwelling.

7. What is the benefit of having an interconnected system of multiple smoke alarms?

8. Describe the basic operation principle of an ionisation type smoke detector.

9. Describe the basic operation principle of a photoelectric type smoke detector.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 2E - 1**	**Revised 07/2014** **UEENEEG033A**

Complete the review questions for Chapter 2 in Electrical Wiring Practice (7th edition) Vol.2 on page 64.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 3 Part B**	**Revised 07/2014 UEENEEG033A**

Alternative supplies:

Topic 7	**Required skills and knowledge:**
	• reasons for the installation of alternative supplies. • types of alternative supply systems. • characteristics and operation of UPSs. • Australian Standards and local requirements for safety services supply systems.

Student Activity	**Done**	
Read **Renewable energy and other alternative supply installations** Electrical Wiring Practice (7th ed.) Vol.2 Page 65 to 83		
Read AS/NZS3000:2018 Section 4.12 Electricity converters		
Read **7.3.1 Uninterruptable power supplies:** Electrical Principles for the Electrical Trade (6th ed.) Vol.2 Pages 140 - 141		
Read **3.3 Uninterruptable power supplies:** Electrical Wiring Practice (7th Ed) Vol 1 Pages 78 to 79		

Alternative power supplies

Alternative supplies are available for remote locations and for standby in the event of a power outage.

Hospitals, airports and many industrial process operations install and regularly maintain standby generators for critical systems.

Types of alternative supplies are:

Photovoltaic (PV) arrays

The Clean Energy Council has reported the total number of Australian households using solar energy increased by 60% from 2002 to 2008 and by July 2009 more than 41,000 homes across Australia had installed solar PV systems. By the end of 2012 the number of households that had invested in solar power was 936,810.

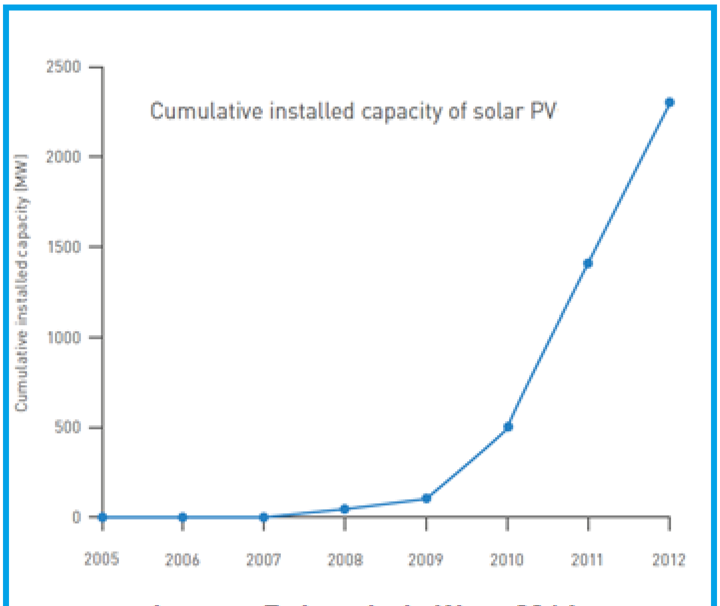


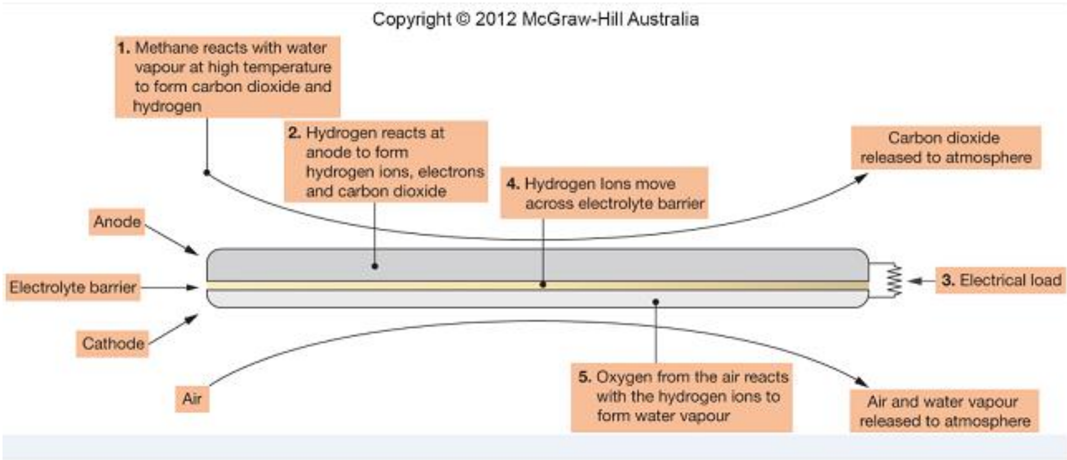
Image - Polytechnic West 2014

PV cells convert sunlight into DC current, which is then converted to AC by an inverter and supplied to the household for use. Excess power that is not consumed by the installation can be fed back into the electricity network.

Energy safety bulletin 52 has an article related to the installation of PV systems:
http://www.commerce.wa.gov.au/energysafety/PDF/EnergyBulletins/energy_bulletin_52.pdf

Fuel Cells

Fuel cells convert fuels like hydrogen or natural gas into electricity by chemical reaction.
The cell consist of an anode, a cathode and an electrolyte that allows charges to move between the two sides of the cell.
Electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity.



Wind Generators

Wind generating systems take advantage of the natural weather systems.

The mid-west of Western Australia is one of Australia's windiest regions.
Wind speeds average 20 to 25 km/h during the cooler months and 25 to 30 km/h from October to March as a result of a strong seasonal sea breeze coupled with a consistent easterly breeze in the morning.

This is Alinta's Geraldton wind farm.
Electricity production begins at wind speeds above 14 km/h.

The 54 turbines standing 78 m tall produce 90 Mw of power that is fed directly into the state electricity grid via an on-site sub-station.

The clean energy created displaces 400 000 tonnes of greenhouse gas emissions produces by traditional fossil fuel based power stations.

Alternative power supplies in Western Australia

The following information is published by the Renewable energy and clean technology directory of innovations and capabilities in Western Australia

Western Australian Renewable Energy and Clean Technology Capabilities

Wind Energy
Wind energy is abundant and easily accessible in many parts of the world, which is why it is one of the most advanced and commercially available renewable energy technologies. Western Australia has a good wind resource and more so in the summer months when energy demand is at a peak.
• Albany Wind Farm – Verve Energy

- Alinta Wind Farm – Babcock & Brown Wind Partners
- Bremer Bay Wind/Distillate – Verve Energy/Horizon Power
- Coral Bay Wind/Distillate – Verve Energy/Horizon Power
- Denham Wind/Distillate – Verve Energy/Horizon Power
- Emu Downs Wind Farm – Griffin Power / Transfield Services
- Esperance, Nine Mile Beach Wind Farm – Verve Energy
- Esperance, Ten Mile Beach Wind Farm – Verve Energy
- Exmouth Wind Farm – Verve Energy
- Hopetoun Wind/Distillate - Verve Energy/Horizon Power
- Kalbarri Wind Farm – Verve Energy
- Modular urban wind turbine system - Windpods
- Rottnest Island Wind/Distillate – Rottnest Island Authority

Photovoltaic

Photovoltaic is a technology that converts light directly into electricity. Photovoltaic (PV) cells use semiconductor metals, most commonly made of silicon, to convert light from the sun directly into an electric current. These cells typically have low maintenance requirements and no refuelling needs.

- Kalbarri Photovoltaic System – Verve Energy
- Horizon Power is working with development partners to build high-penetration hybrid solar photovoltaic diesel power stations at Marble Bar and Nullagine

Solar Thermal

Solar thermal technology refers to the capture and utilisation of solar energy for use in heat or electricity production.

- Rockingham Photovoltaic Trough Concentrating: System – Verve Energy

Geothermal Energy

Geothermal energy is heat energy originating deep in the earth's molten interior. It is responsible for tectonic plates, bubbling mud pools, hot springs, volcanoes and earthquakes. Geothermal energy is a proven resource for direct heat and power generation.

There are at least four swimming pools in the Perth region heated by geothermal systems:

- Challenge Stadium
- Christchurch Grammar School
- Claremont Pool
- Craigie Leisure Centre, City of Joondalup
- Riverton Leisureplex, City of Cannington

Biomass

Biomass is any recent organic matter that can be used as fuel. It can be used directly for electricity production, heating, cooking or indirectly by converting it into a liquid or gaseous fuel.

- Mandurah Biomass Gasification facility – Mount Herron Engineering
- Muja biomass co-firing – Verve Energy
- Manjimup (proposed) Biomass power facility – Western Australian Biomass
- Woodman Point sewage processing – Water Corp
- Shenton Park (proposed) biomass processing trial facility – AnaeCo Ltd

• Integrated Wood Processing demonstration facility, Narrogin – Verve Energy
• Perth metropolitan (1 site) landfill gas project – Waste Gas Resources
• Perth metropolitan (2 sites) landfill gas project – AGL Energy Services
• Perth metropolitan (2 sites) landfill gas project – Landfill Management Services
• Perth metropolitan (4 sites) landfill gas project – Landfill Gas and Power

Hydroelectricity Generation
Hydroelectric power is electricity produced by the movement of water from rivers and lakes driving a water turbine and a generator producing electricity.
• Ord River Hydro – PacificHydro
• Pemberton Hydro Station – South West Development Commission Tidal Energy

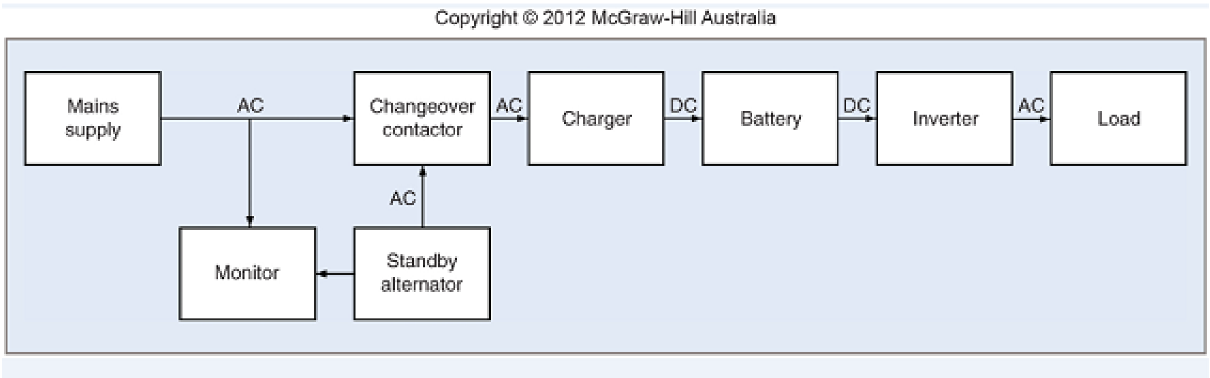
Energy Abatement
In energy abatement, waste heat from industrial processes or power generation is used by complementary industries, thus reducing overall electricity demand.
• Alinta's Pinjarra Cogeneration with Alcoa
• Alinta's Wagerup Cogeneration with Alcoa

Uninterruptable power supplies

Read 7.3.1 Uninterruptable power supplies: Electrical Principles for the Electrical Trade (6th ed.) Vol.2 Pages 140 - 141
Read 3.3 Uninterruptable power supplies: Electrical Wiring Practice (7th Ed) Vol 1 Pages 78 to 79.

To maintain vital systems in the event of power outage uninterruptable power supplies uses banks of rechargeable batteries that, with the use of an inverter that can convert dc to ac, provide backup of the supply for a short period.
As shown in the flow chart this allows time for a standby alternator to come into service and provide power until the mains power is returned.

This back up is essential for hospitals, airports and many industrial processes where an unplanned shut down could prove a danger to people or equipment or costly loss of material.



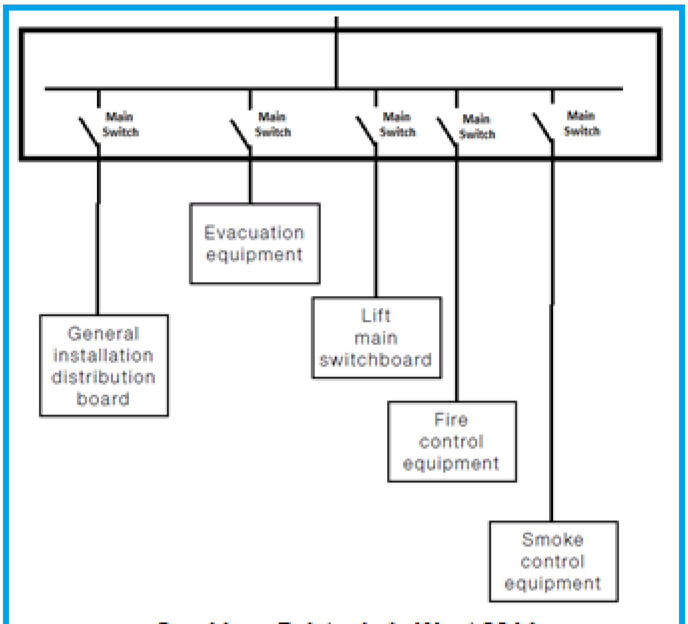
An alternative to battery storage is the flywheel system. This technology uses a mechanical flywheel that is continually driven at speed, which stores sufficient energy to ride through power disturbances such as dips or surges in voltage and current.

The UPS system can be a simple back up system or an integrated power conditioning system that, through an inverter system, continually provides a filtered supply free of any noise or distortion to the load. This allows critical data systems to run with reduced chance of errors.

Safety Services

Requirements for safety services as set out in Clause 7.2 of AS/NZS3000:2018 and apply to the electrical installation of building services that are essential for the safe operation of the safety services consisting of fire detection, warning and extinguishing systems, smoke control systems, evacuation systems and the safety of persons using lifts.

The requirements are intended to ensure that electricity supply is not inadvertently disconnected from electrical equipment that is required to operate during emergency conditions for which there is no alternative supply.



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Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 3B -1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. List the common types of alternative energy sources available in WA.

2. What systems are deemed to be covered by the term Safety Services?

3. How many main switches are permitted in an installation that incorporates Safety Services

4. What is the AS/NZS3000:2018 clause number that related to the above question?

5. What is the requirement of marking of main switches for Safety services?

6. What is the AS/NZS3000:2018 clause number that related to the above question?

7. What are two types of energy storage systems that are commonly used by industry for maintaining an uninterruptable power supply?

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Activity Sheet 3B - 2**	**Revised 07/2014** **UEENEEG033A**

Complete the review questions for Chapter 3 in Electrical Wiring Practice (7th edition) Vol.2 on pages 83 to 84.

Notes:

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Study Guide Section 3 Part C**	**Revised 07/2014 UEENEEG033A**

Installation of batteries:

Topic 8	Required skills and knowledge:
	• common types of primary cells and secondary batteries and typical applications. • terminal voltage of common primary cells and secondary cells. • correct storage, handling and disposal techniques for cells and batteries. • charge/discharge cycle for a secondary cell. • effect of internal resistance on a secondary cell. • state of charge of a secondary cell. • installation of batteries as per AS/NZS3011 • commissioning procedures for various secondary batteries. • safe working procedures when working with secondary cells and batteries.

Student Activity	Done	
Read **Cells and batteries:** Electrical Principles for the Electrical Trade (6th ed.) Vol.1 Page 190 - 206		
AS/NZS3000:2018 Section 4.17 Batteries refer to AS3011.1 and AS3011.2		
AS2676.1:1992 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings Part 1: Vented cells		
AS2676.2:1992 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings Part 2: Sealed cells		
AS3011.1 :1992 Electrical installations — Secondary batteries installed in buildings Part 1: Vented cells		
AS3011.2 :1992 Electrical installations — Secondary batteries installed in buildings Part 2: Sealed cells		

Batteries

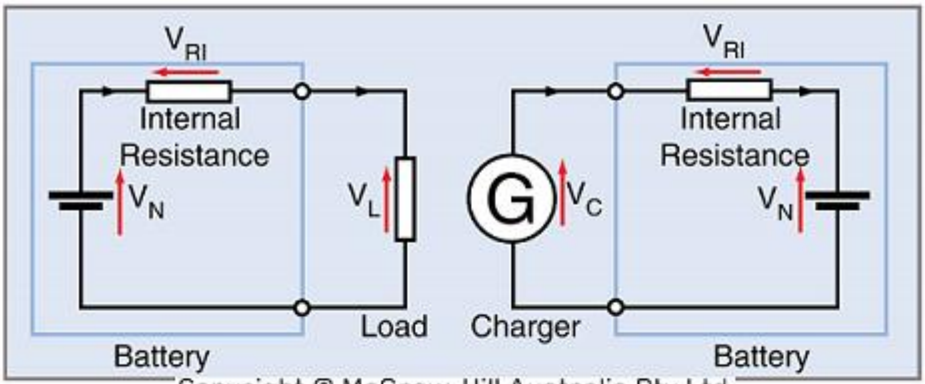
Read sections 11.0, 11.1 and 11.2 on pages 190 to 194 of Chapter 11 in Volume 1 of Electrical Principles for the Electrical Trades 6th edition.

Batteries are made up of a number of cells connected together to provide the required output voltage and current required for an application.

The basic measure of a cell and subsequent battery is the nominal output voltage. The measured terminal voltage can vary depending on the state of charge and the load, The open circuit voltage of a fully charged battery with a nominal voltage of 12 V can be 12.6 V. The on load voltage of the same battery can be 11.5 V.

This drop in voltage from open circuit to fully loaded is due to the internal resistance of the battery.

This diagram represents the internal resistance of the cell or battery during both charging and discharging.



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There are two basic types of cells.

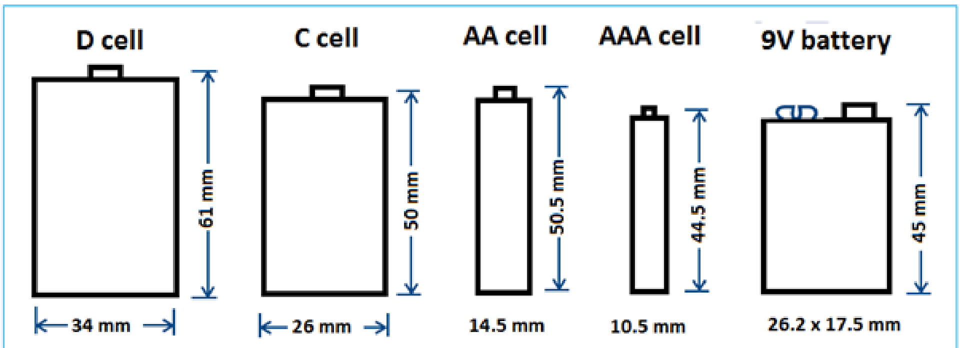
- Primary
- Secondary

Primary cell:

Read section 11.5 on pages 197 to 198 of Chapter 11 in Volume 1 of Electrical Principles for the Electrical Trades 6th edition.

A primary cell is usually not rechargeable and is discarded after discharging. Common examples are Carbon-zinc, alkaline, mercury, silver oxide and lithium.
They are used extensively in a broad range of portable electrical and electronic equipment.

Common sizes are:



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The following table shows a comparison of the common primary cells and their applications.

Cell type	Nominal cell V	Discharge rate	Applications
Carbon-zinc	1.5	Medium	Torches, toys and electronic equipment
Alkaline	1.5	High	Heavy duty torches, photoflash, digital cameras, portable audio devices
Lithium	3	Medium to high	Watches, calculators, test instruments
Mercury	1.35	Low	Pagers, hearing aids, watches, calculators
Silver oxide	1.5	Low	Pagers, hearing aids, watches, calculators

Secondary cell:

Read sections 11.6 on pages 198 to 203 of Chapter 11 in Volume 1 of Electrical Principles for the Electrical Trades 6th edition.

Secondary cells are rechargeable with the use of a charger suited to the type of cell.

The range of common secondary cells include, but are not restricted to:

Lead acid
Nickel-cadmium
Nickel-metal-hydride
Lithium-ion.

Cell type	Nominal cell V
Lead acid	2
Nickel Cadmium	1.2
Nickel-metal-hydride	1.2
Lithium-ion (Cobalt)	3.6

Lead Acid

The lead acid battery has been the workhorse of electrical storage for well over 100 years. Its rugged design and ability to deliver high currents for a short duration has made it ideal for use by the motor vehicle industry.

There are various types of lead acid batteries available:

- Wet or flooded
- Valve regulated lead acid (VRLA)

The VRLA battery can be the absorbed glass matte (AGM) or the gel type and the positive plates can be the flat or tubular type.

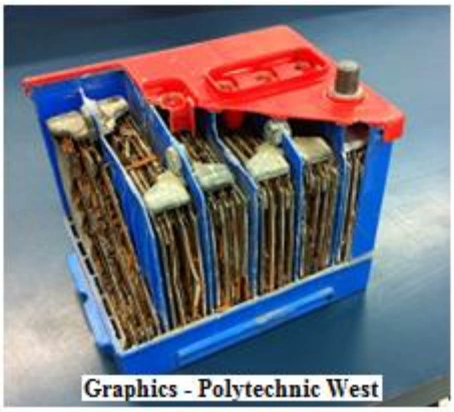
Each cell of the lead acid battery consists of interleaved plates impregnated with lead dioxide for the positive plates and sponge lead for the negative plates with sulphuric acid diluted in distilled water as the electrolyte.

When topping up a wet or flooded battery with a low electrolyte level only distilled water is usually required to be added. Distilled water is used because it is free of the impurities of tap water that would be detrimental to the chemical process and therefore reduce the battery output and life.

During the charging and discharging cycles the specific gravity of the electrolyte will change. For a flooded or wet cell lead acid the state of charge of a cell can be determined by using a hydrometer that draws up a quantity of electrolyte into a chamber and uses a float to give a reading. A fully charged cell will have a reading 1.250. Most hydrometers simply have colour coded zones of green for charged and red for discharged. Any significant variation of cell readings within a battery is an indication of end of serviceable life.

Another way to determine the state of a battery is to do a load test where half of the rated cold cranking current of the battery is maintained for 15 seconds and the battery terminal voltage for a 12 V battery does not drop below 9.5 V.

It is important not to leave a lead acid cell discharged for any period of time as sulphation of the plates will occur reducing the output and the life of the battery.



This image is a 12 V lead acid battery that has been cut away to show the six separate cells that have a nominal terminal voltage of 2 V.
Each of the cells are made up of interleaving plates to increase the overall capacity

A chemical reaction occurs within each cell battery during both the discharging and charging cycles.

Led acid discharge cycle

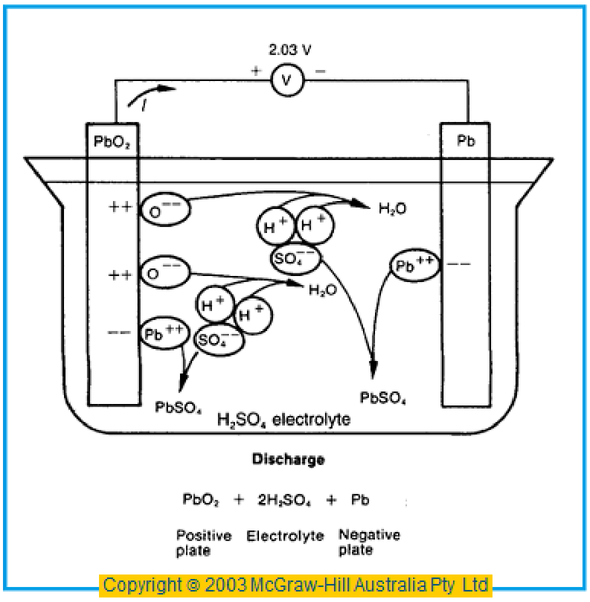
The sulphuric acid is depleted on the discharge cycle.

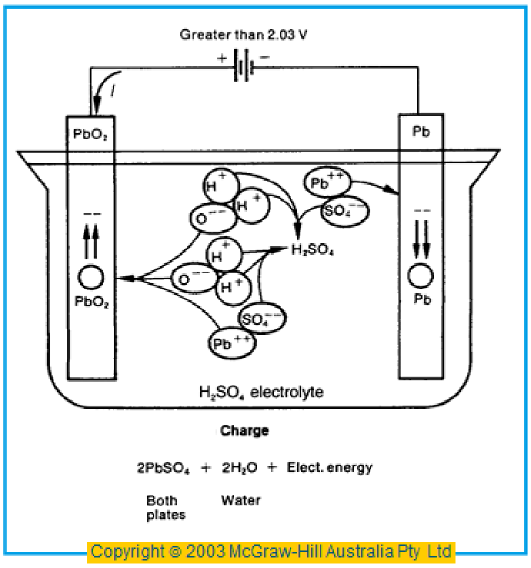
The acid ionises in the water to form positive hydrogen ions (H+) and negative sulphate ions (SO_4^{--}).

Lead atoms leave both plates and combine with the sulphate ions to form lead sulphate.

At the same time ionised oxygen atoms from the lead peroxide combine with the hydrogen ions to form water in the electrolyte.

In this process the lead from both plates is used up and the electrolyte is diluted.





Lead acid charge cycle

By connecting the battery to an external charger the cells can be recharged.

The sulphuric acid is regenerated on the charge cycle.

The chemical reaction is the reversal of that described in the discharge cycle and the chemical energy is restored.

Nickel-cadmium

The basic makeup of the nickel-cadmium cell is similar to lead-acid in the fact that there are two dissimilar metals in an electrolyte.
The electrodes are nickel and cadmium with an electrolyte of potassium hydroxide.

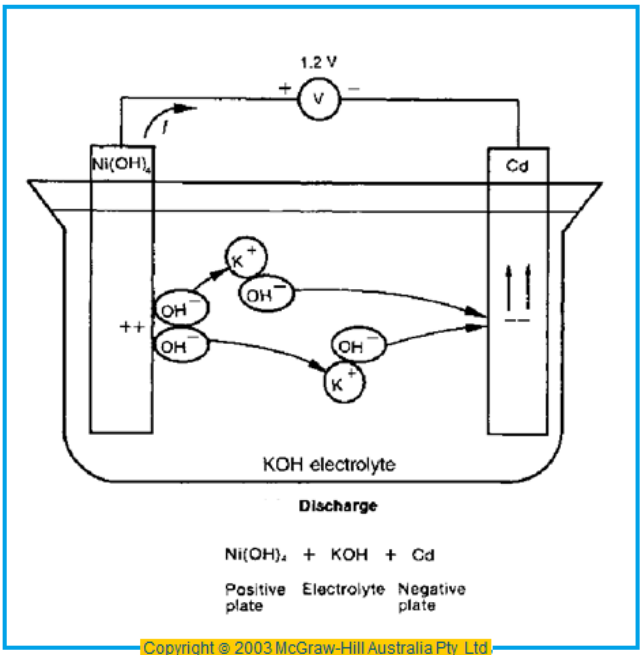
Nickel cadmium discharge cycle

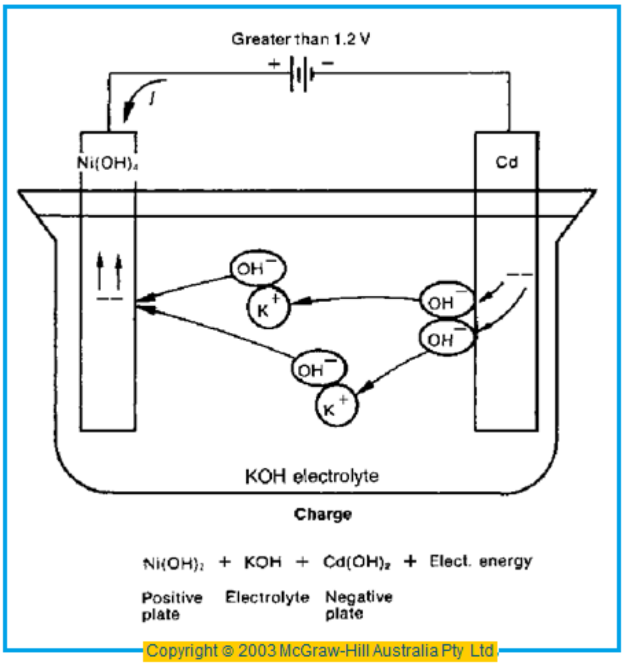
The electrolyte breaks down into potassium ions (K^+) and hydroxide ions (OH^-).

The potassium ions attract hydroxide ions from the positive plate converting the nickel hydroxide into $Ni(OH)^2$ leaving a net positive charge.

Hydroxide ions from the electrolyte combine with the negative plate to form cadmium hydroxide $Cd(OH)^2$ leaving a net negative charge.

The electrolyte condition remains constant during this process.





Nickel cadmium charge cycle

The electrolyte breaks down into potassium ions (K^+) and hydroxide ions (OH^-) during the charging cycle when connected to an external charger.

The hydrogen ions now migrate in the reverse direction from the discharge cycle.

Potassium ions attract hydroxide ions from the negative plate converting it back to cadmium.

The hydroxide ions move to the positive plate converting it back to its original form.

The electrolyte takes no part in the process apart from acting as a vehicle for the passage of ions.

Battery maintenance

Read sections 11.4 on pages 196 to 197 of Chapter 11 in Volume 1 of Electrical Principles for the Electrical Trades 6th edition.

Battery maintenance is essential for the safe and efficient operation of the installed systems. Different types of batteries require different testing and inspection techniques. It is important to refer to and follow the manufacturer's instructions and recommendations.

The types of failure modes will vary depending on the type of battery involved.

With all batteries a general visual inspection will include checking for leakage or gassing of electrolyte, terminal corrosion and overall condition.

Battery testing

The various testing techniques used will also depend on the type of battery and whether or not the cell is the flooded type. Again it is important to follow the manufacturer's instructions.

Common testing techniques include:

- Terminal voltage
- Hydrometer testing for flooded lead acid
- Simple load testing
- Resistance testing

Other testing techniques that require specialised equipment include:

- Capacity testing
- Impedance testing – injection of an ac current

Safety precautions

Read sections 11.3 on page 195 of Chapter 11 in Volume 1 of Electrical Principles for the Electrical Trades 6th edition.

The lead acid battery will give of hydrogen gas during the charging cycle so it is important to maintain a battery charging area as ignition free meaning no smoking or ignition sources nearby.

If dealing with the mixing of acid and distilled water it is always important to pour the acid into the water while stirring with a glass rod. Never pour distilled water into acid as a violent chemical reaction can occur.

When handling any acid or if dealing with a nickel cadmium battery that has an alkaline electrolyte it is essential to wear a rubber apron and gloves as well as a face shield.

If electrolyte is spilled or splashed onto clothing, or your body, wash with water and neutralise with a solution of baking soda & water. Electrolyte splashed into eyes is extremely dangerous. If this occurs, gently open eyes and wash with cool clean water for five minutes. Call a doctor

If you are dealing with a combination of both lead acid and nickel cadmium batteries it is essential that the chemicals and the equipment for them are kept apart.

Read section 8 'Safety' of AS2676.1:1992
It provides safety precautions to be followed when installing or maintaining batteries both with acid or alkaline electrolytes.
It is important to have the correct PPE and understand the signage requirements when working with batteries.

Other important considerations are how to deal with electrolyte burns and the administration of first aid.

Battery installation requirements

The Australian standards set of AS2676 provides guidance for the installation, maintenance and testing of vented and sealed secondary cells in buildings and are to be read in conjunction with the set of AS3011 of standards that sets out the requirements for the safe installation of battery banks where the nominal voltage exceeds 24 V and a capacity exceeding 10 A.h.

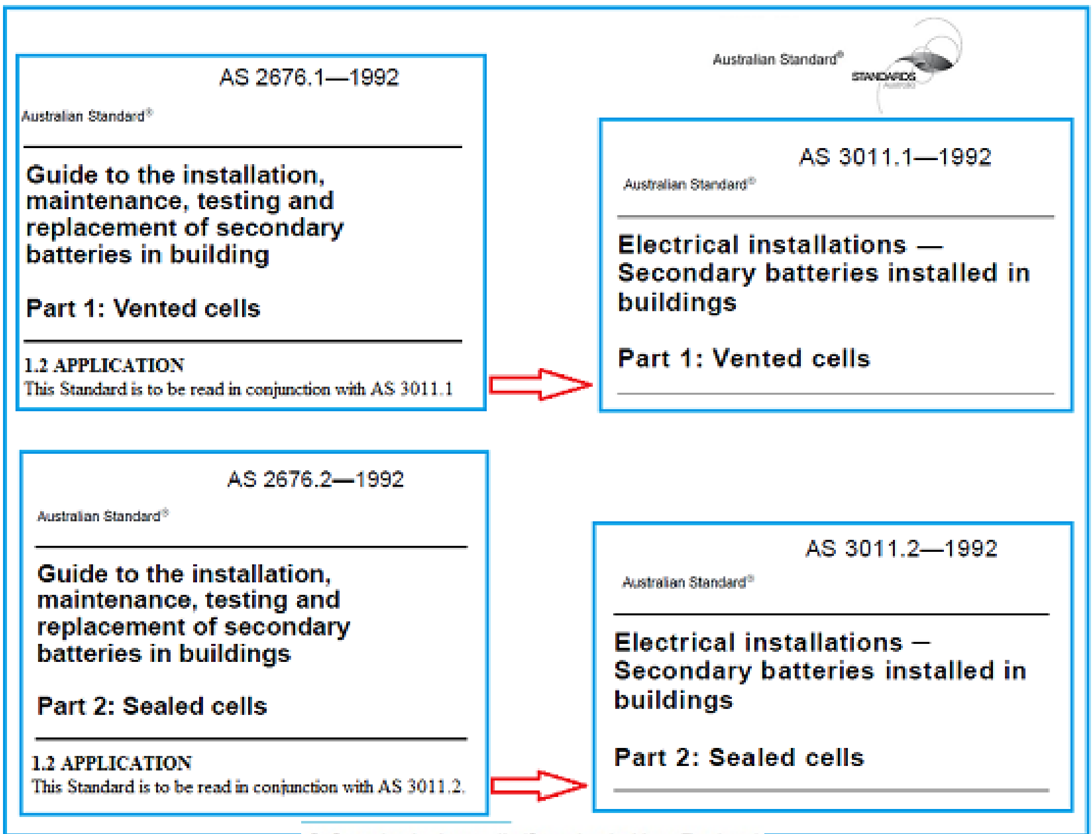
Batteries need to be installed in a dedicated battery room, a battery enclosure designed to specifications or in an area that is restricted to authorised personnel only. This is due to the volatile nature of batteries and the low voltage levels that are present.

A main isolating switch, earth leakage detection and circuit protection by fuse or circuit breaker are required.

Batteries of cells are not permitted to exceed 120 V without being sectionalised with barriers and provided with isolation devices.

Luminaires and socket outlets have minimum distances from both batteries and vents for safe operation.

The Australian standard AS3011.1 :2009 Covers the installation of secondary batteries with vented cells and AS3011.2 :2009 covers the installation of secondary batteries with sealed cells.


AS 2676.1—1992

Australian Standard®

Guide to the installation, maintenance, testing and replacement of secondary batteries in building

Part 1: Vented cells

1.2 APPLICATION
This Standard is to be read in conjunction with AS 3011.1

Australian Standard® STANDARDS

AS 3011.1—1992

Australian Standard®

Electrical installations — Secondary batteries installed in buildings

Part 1: Vented cells

AS 2676.2—1992

Australian Standard®

Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings

Part 2: Sealed cells

1.2 APPLICATION
This Standard is to be read in conjunction with AS 3011.2.

AS 3011.2—1992

Australian Standard®

Electrical installations – Secondary batteries installed in buildings

Part 2: Sealed cells

© Standards Australia/Standards New Zealand

It highlights the dangers of hydrogen gas emission during the charging process and the high concentrations in the event of overcharging. It requires suitable means to prevent charging beyond the manufacturer's recommended limits. Alarms or automatic shut down processes are required to protect from this dangerous situation.

Although a sealed cell will not emit hydrogen under normal charging a danger still exists under abnormal conditions.

Minimum space requirements are set down for battery rooms as well as ventilation requirements. Terminal shrouding is required and the need to be able to maintain and service each cell without the need to lean over other cells is important for the safe facilitation of maintenance.

The 'Health (Public Buildings) Regulations 1992' for Western Australia require any room or enclosure in which batteries with a stored capacity exceeding 1 kWh or with a floating voltage exceeding 115 V shall conform to the installation requirements of AS2676.1 or AS2676.2.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Worksheet 3C -1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. List three common types of primary cells and give an application for each.

2. For each of the primary cells you have provided in the above question what is the nominal cell voltage?

3. List two common types of secondary cells and give an application for each.

4. For each of the secondary cells you have provided in the above question what is the nominal cell voltage?

5. What is the difference between a primary and secondary cell?

6. What does a hydrometer test result for a flooded lead acid battery provide you with?

7. What does a hydrometer test result for a flooded nickel cadmium battery provide you with?

8. List the required PPE that should be used if you are handling or mixing acid or alkaline electrolytes.

9. If you are dealing with the mixing of sulphuric acid and distilled water you should:

A Pour the water into the acid
B Pour the acid into the water
C Pour the acid and water together
D Keep the acid and water separate

10. How does the internal resistance of the battery affect its output?

11. What safety precautions should be observed if you are handling both lead acid and nickel cadmium batteries in the same workshop?

12. Referring to AS3011.1 :2009 Vented cells, what is the voltage where inter-block barriers are required to be installed to sectionalize the batteries into voltage blocks?

13. Referring to AS3011.1 :2009 what are the restrictions for the installation of lighting in a battery room?

14. What is meant by the term polarisation?

15. What is meant by the term local action?

17. What is the difference between and cell and a battery?

Notes:

Government of Western Australia North Metropolitan TAFE	Solve problems in single and three phase low voltage electrical apparatus and circuits	Study Guide Section 4 Part A	Revised 07/2014 UEENEEG033A

Lighting circuits

Topic 1	Required skills and knowledge:
	• the "loop at the light" method of wiring lighting circuits. • the "loop at the switch" method of wiring lighting circuits • wiring diagrams for the lighting circuit of an installation that incorporates one-way, two-way and two-way and intermediate switching of light points using the loop at the light/switch methods of TPS wiring. • TPS cabling requirement for the loop at the light/switch circuit. • installation methods of accessories and wiring for a lighting circuit incorporating one-way, two-way and two-way and intermediate switching of lighting points using the loop at the light/switch method of TPS wiring. • correct operation of the install circuits including testing for correct compliance with Australian Standards.

Student Activity	Done	
Read **Circuits in general wiring** Electrical Wiring Practice (7th ed.) Vol.1 Page 146 to 149		
Read **General switching, lighting and socket outlet accessories** Electrical Wiring Practice (7th ed.) Vol.1 Page 121 to 128		
Read **Testing techniques** Electrical Wiring Practice (7th ed.) Vol.1 Page 252 to 283		
Read AS/NZS3000:2018 Section 4.5 Lighting and Section 8 Verification		

Lighting Circuits

There are various ways that the electrical contractor can choose to connect a lighting circuit depending on the customer requirements and the most economical solution.
The common methods are:

- Loop at the light
- Loop at the switch
- Loop at the junction box

A looping terminal that plays no functional part of either the light fitting or the switch is provided with many of these fittings for the sole purpose of looping in and out.

Loop at the light

Looping at the light utilises the loop terminal that is available with many light fittings.

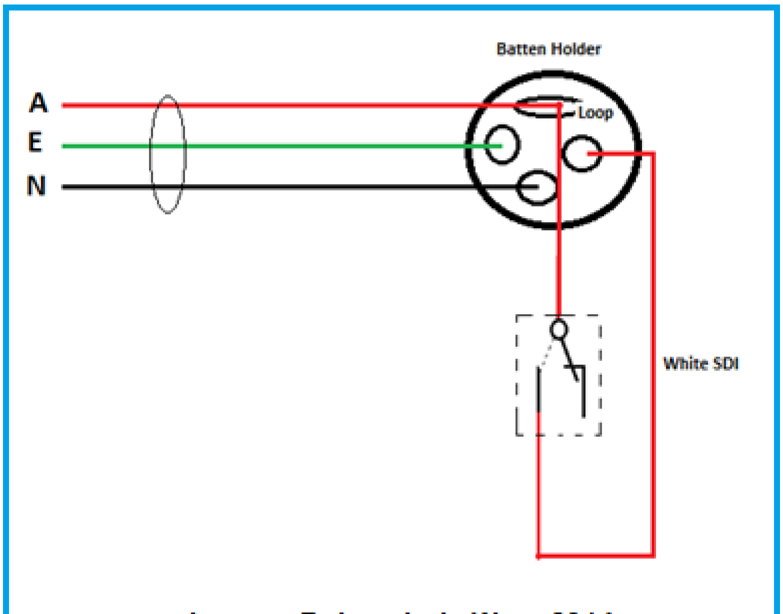


Image - Polytechnic West 2014

Loop at the switch

Looping at the switch utilises the loop terminal that is available with many two way switch mechanisms. The neutral is looped in and out and the earth conductors can be joined with either a two screw connector or a soldered joint.

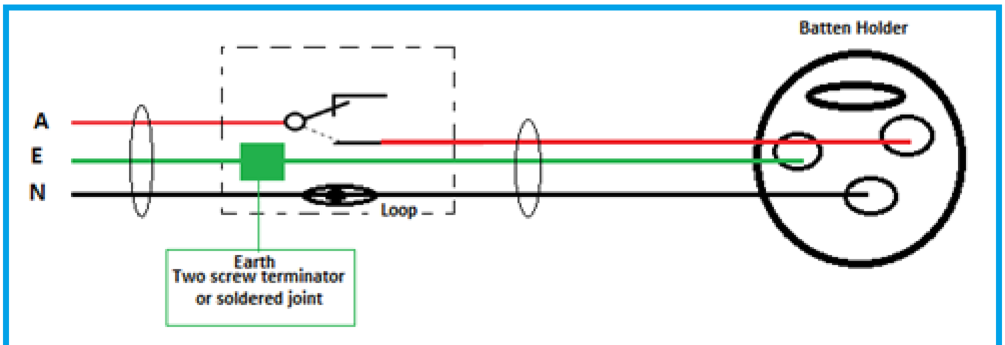
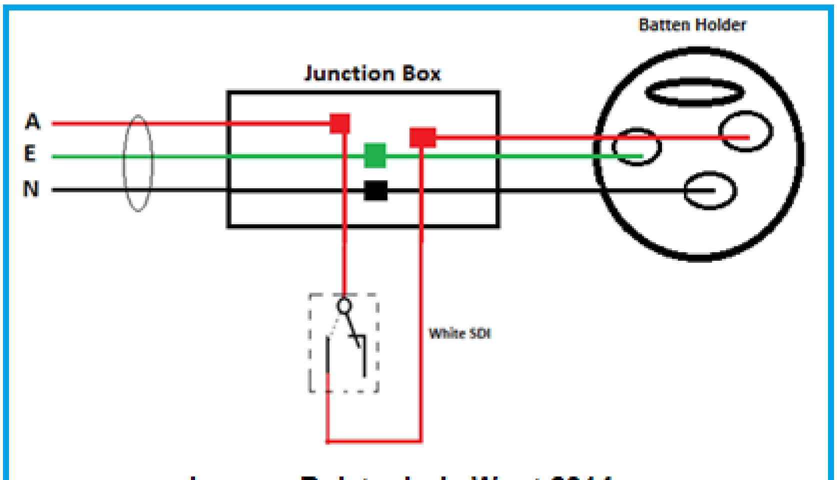


Image - Polytechnic West 2014

Loop at the junction box

Looping at the junction box has the added expense of the box but may be required if there is no looping available at the light fitting. Some contractors choose this method to simplify final fit off as there are only active neutral and earth to terminate



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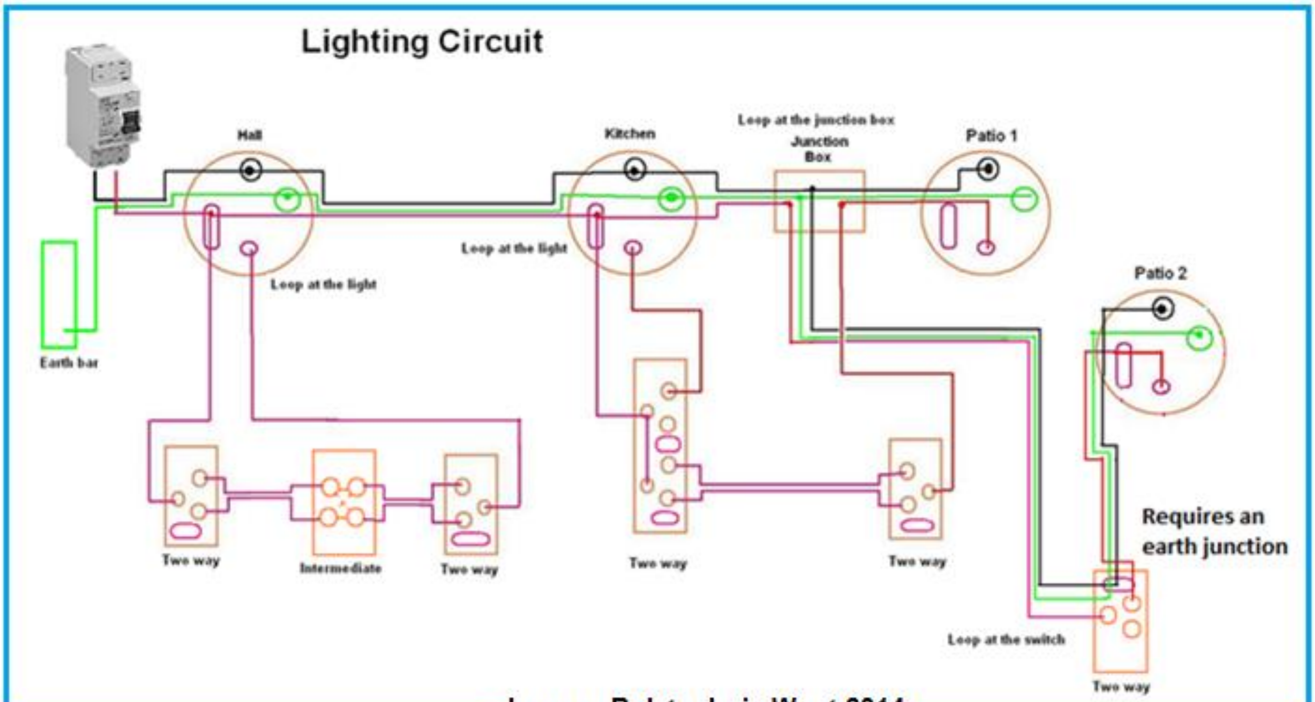


Image - Polytechnic West 2014

One-way Lighting Circuit
A one way lighting circuit is a circuit in which one or more lamps are controlled from a single switch.

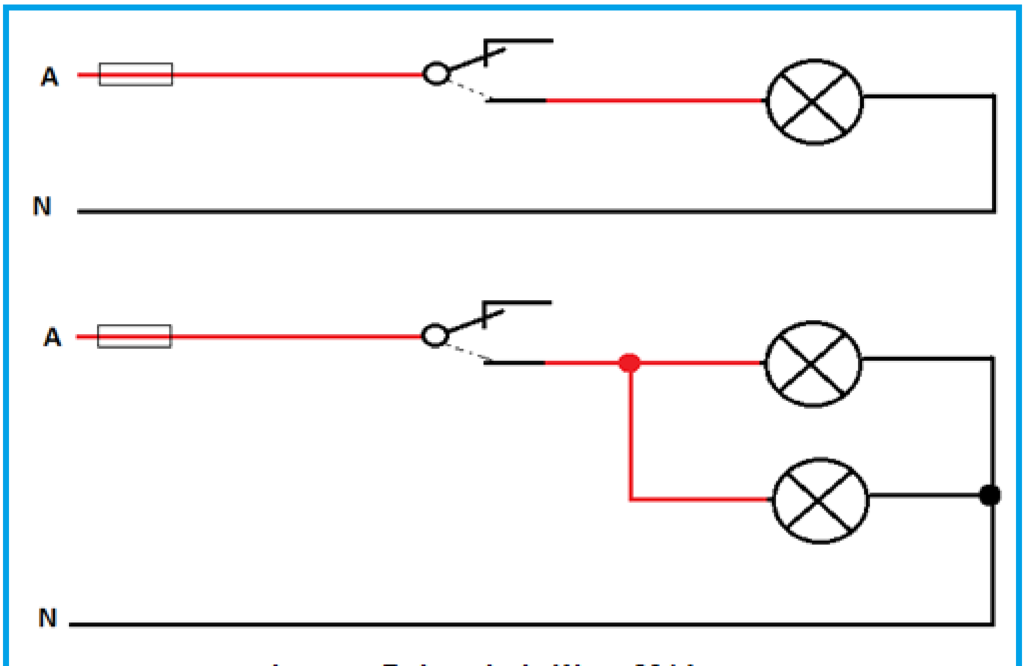


Image - Polytechnic West 2014

Two-way Lighting Circuit
A two-way lighting circuit is a circuit in which one or more lamps can be switched on or off from two different switches. A two-way circuit requires two SPDT (single pole double throw) switches. Two different methods of connecting a two way circuit are shown below.

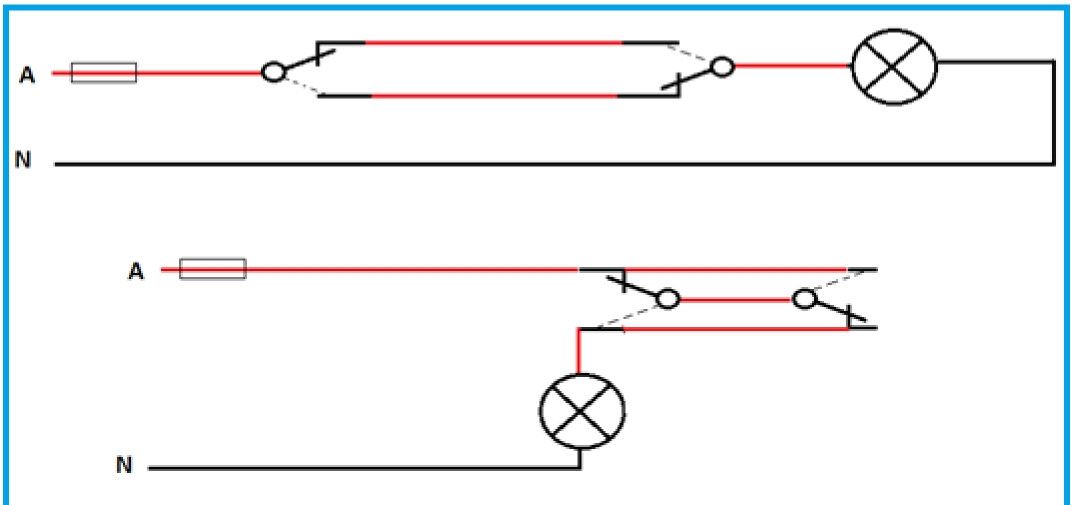


Image - Polytechnic West 2014

Three-way Lighting Circuit

A three-way lighting circuit is a circuit in which one or more lamps can be switched on or off from three different switches. A three-way circuit requires two SPDT (two-way) switches and one intermediate switch as shown below.

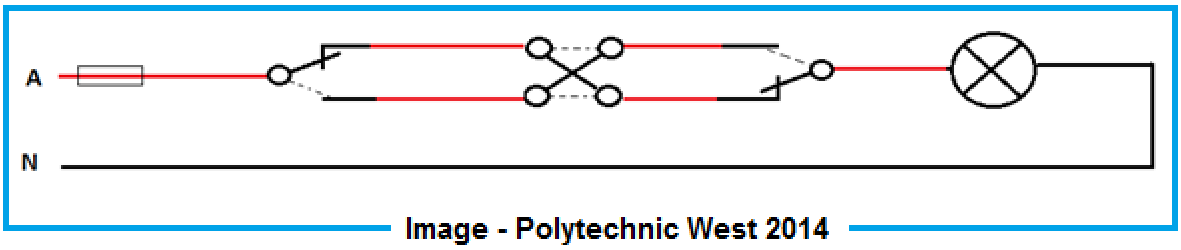


Image - Polytechnic West 2014

Multi-way Lighting Circuit

A multi-way lighting circuit is a circuit in which one or more lamps can be switched on or off from four or more different switches. A multi-way circuit requires two SPDT, one at each end of the control circuit and two or more intermediate switches. A multi-way can be made to have any number of switch positions by adding intermediate switches.

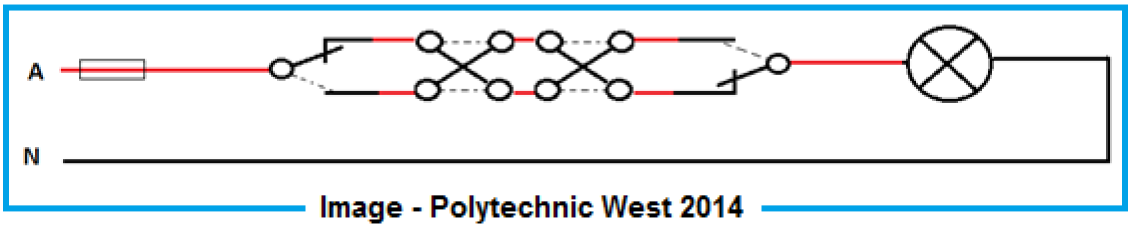


Image - Polytechnic West 2014

Master on control circuit

In the off position the master on switch allows all the lighting circuits to act independently. In the on position all lights are forced on.

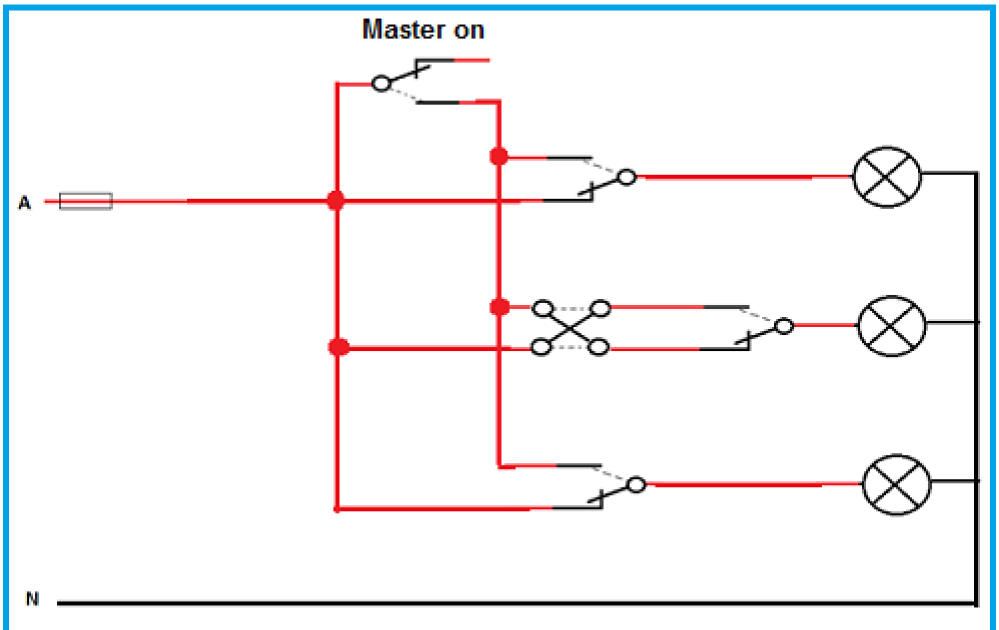


Image - Polytechnic West 2014

Installation practices:

The AS/NZS3000:2018 Wiring rules sets out the requirements for the installation, verification and testing of lighting circuits.

Section 4.5 covers the requirements for the safe installation of lighting.

One key factor is that lamps and the associated equipment give off heat and the electrical installer must consider the clearance requirements from flammable material in ceiling spaces.

The Energy safety bulletin, found on the energy safety website, numbers 42, 51 and 60 have highlighted the dangers and the associated fires that have been caused by incorrectly installed light fitting and associated transformers that have been too close to flammable insulation material.

Bulletin number 62 April 2013 highlights the following changes from amendment 2 in regards to the installation of down lights:

Clause 4.5.2.3 and the associated Figure 4.9 showing minimum clearances, have been changed. They now relate to all types of recessed luminaires (including LEDs, not just incandescent and halogen). The new amendment emphasises that installers must ensure luminaires comply with a range of requirements including new signage arrangements to advise anyone entering the roof space that down lights have been installed.

Clause 4.5.2.3.4 - Classification of recessed luminaires and the associated Table 4.3 provides guidance to applications and general restrictions of use of recessed light fittings.

Energy safety website:
http://www.commerce.wa.gov.au/EnergySafety/PDF/EnergyBulletins/index.html

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Work sheet 4A - 1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. Explain the difference between the loop at the light and the loop at the switch method of installing a lighting circuit.

2. Draw a circuit diagram of two lamps controlled by a single switch.

3. Draw a circuit diagram of one lamp controlled by a two way circuit.

4. Draw a circuit diagram of two lamps controlled by a three way circuit.

5. Draw a wiring diagram of two lamps controlled by a two way circuit using the loop at the light method.

6. Referring to the clearance requirements of luminaires from combustible insulation materials in the Wiring rules complete this table:

Dimension	Clearance
A – Clearance above luminaire	
B – Side clearance to combustible building element	
C – Side clearance to bulk thermal insulation	
D – Clearance to auxiliary equipment (transformer for example)	

7. What are the requirements of the wiring rules if a lamp to be installed is near flammable material?

8. Please provide the AS/NZS3000 clause number for the previous question.

9. The installation of a warning sign is required by the wiring rules if recessed lights are installed. Where is this sign to be located?

10. What minimum size lettering is required for this warning sign.

11. Please provide the AS/NZS3000 clause number for the previous question.

12. What is the AS/NZS60598.1 symbol for **Do not cover** in relation to luminaires.

13. Section 8 of the wiring rules sets out the requirements for verifying any installation or part thereof. Complete the following:

To confirm that the requirements of this Standard have been met, after completion and before being placed in service, the installation shall.be—

(a) ___________________________________

(b) ___________________________________

14. What is the maximum allowed resistance value of the protective earthing conductor of a 1.5 mm^2 lighting circuit that is protected by a ten amp C type circuit breaker according to Table 8.2?

15. What particular requirements are to be met when carry out an insulation resistance test for a three way lighting circuit?

16. What is the test voltage required for insulation resistance testing of a lighting circuit?

17. Describe the testing procedure for checking the polarity and correct circuit connections for a lighting circuit.

Government of Western Australia North Metropolitan TAFE	Solve problems in single and three phase low voltage electrical apparatus and circuits	Study Guide Section 4 Part B	Revised 07/2014 UEENEEG033A

Circuits for socket outlets

Topic 2	Required skills and knowledge:
	Circuits for socket outlets encompassing: the purpose of socket outlets. requirements concerning the polarity of switched socket outlets. correct cable size to supply 10 A, 15 A and 20 A socket outlets (single and three phase), for given installation conditions. number of socket outlets connected to a 16 A and 20 A circuit breaker. installation methods of a single phase socket outlet circuits. correct operation of the installed circuits including testing (dead testing only) for correct compliance with Australian Standards.

Student Activity	Done	
Read **Circuits in general wiring** Electrical Wiring Practice (7th ed.) Vol.1 Page 146 to 149		
Read **General switching, lighting and socket outlet accessories** Electrical Wiring Practice (7th ed.) Vol.1 Page 121 to 128		
Read **Testing techniques** Electrical Wiring Practice (7th ed.) Vol.1 Page 252 to 283		
Read AS/NZS 3000:2018 Section 4.4 Socket outlets and Section 8 Verification		

Circuits for Socket Outlets

Socket outlets are to meet all the requirements of AS/NZS3000:2018 Wiring rules and the WA Electrical Requirements 2014 (WAER).

Table 3.3 of the Wiring rules and Section 9.9 of the WAER require a minimum cross-sectional area of conductors for final sub-circuits supplying socket outlets to be not less than 2.5mm².

An exception to this is the installation of socket outlets on lighting circuits for the connection of luminaires and other appliances rated at not more than 150 watts.

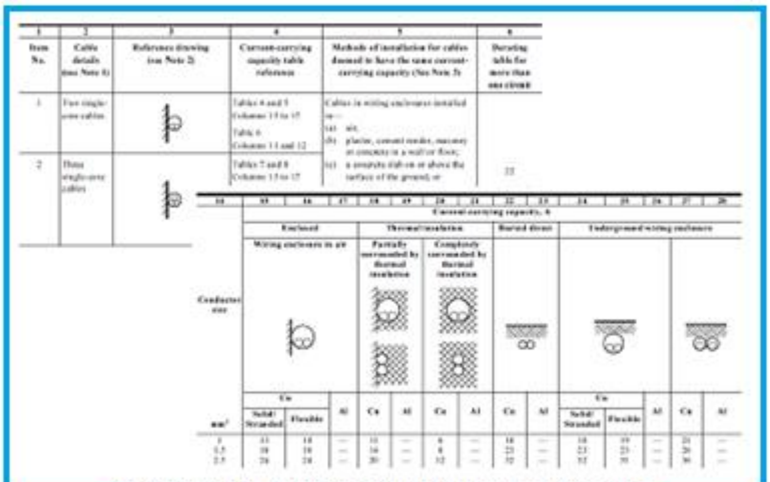
Clause 1.6.5 of the AS/NZS300:2018 requires that every electrical installation shall be divided into circuits to avoid danger and minimize inconvenience in the event of a fault, and facilitate safe operation, inspection, testing and maintenance.

We are provided with guidance on how many socket outlets we can install on a final sub circuit in table 'C8 Guidance on the loading of points per final sub circuit' in the Wiring rules.

The number of socket outlets that can be installed will depend on whether the installation requires 10, 15 or 20 A outlets, the associated conductor size of the final sub circuit and the size of the circuit protective device.

Installation methods for socket outlet circuits will depend on the type of structure and the customer requirements.

AS/NZS 3008 1.1:2017 provides us with guidance on current carrying capacities and voltage drop limitations for the range of different cables installed in the range of construction options.



These are a selection of different construction types for domestic buildings.

Photos Ian Evans Electrical Lecturer

In AS/NZS3008.1.1 Selection of cables, we use tables 3(1) Unenclosed in air, 3(2) Enclosed, 3(3) Buried direct in the ground and 3(4) Enclosed in underground pipes and ducts to guide us in the selection process for determining current carrying capacities for the varying installation methods.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Work Sheet 4B - 1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

1. What is the minimum cross sectional area size of socket outlets?

2. Please give the associated AS/NZS300:2018 clause or table relating to the above question.

3. Complete the following statement:

Socket-outlets shall not be installed where the withdrawal of a plug from the socket-outlet is restricted by a ________________ _______________ or __________ within the installation.

4. Is an earthing contact required to be provided with every socket outlet?

5. Please give the associated AS/NZS300:2018 clause or table relating to the above question.

6. What is required to be marked on socket outlets installed for connection to extra low voltage?

7. Please give the associated AS/NZS300:2018 clause or table relating to the above question.

8. Are socket outlets required to be controlled by a switch?

9. Please give the associated AS/NZS300:2018 clause or table relating to the above question.

10. Indicate on this drawing the correct polarity for a socket outlet.

Image - Polytechnic West 2014

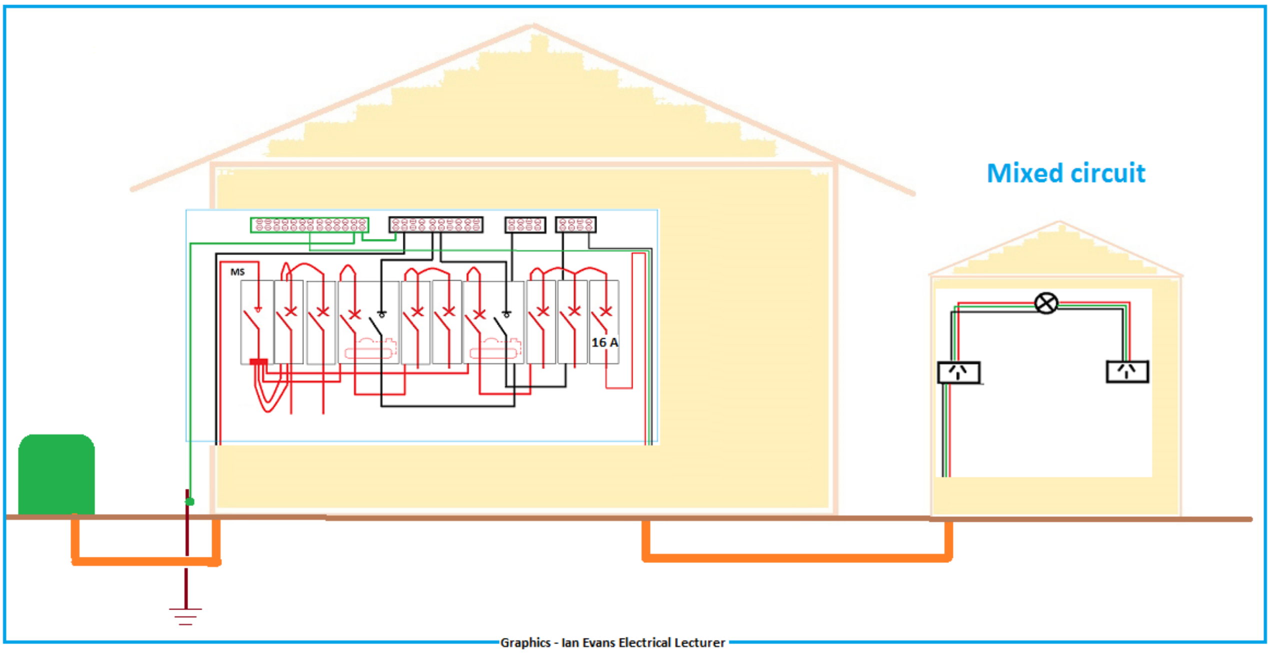
11. Please give the associated AS/NZS300:2018 relating to the above question.

Government of Western Australia North Metropolitan TAFE	Solve problems in single and three phase low voltage electrical apparatus and circuits	Study Guide Section 4 Part C	Revised 07/2014 UEENEEG033A

Final sub-circuits and segregation:

Topic 3	Required skills and knowledge:
	• purpose of mixed circuits. • circuit loading for a mixed circuit. • purpose of segregation of circuits and the AS/NZS3000 requirements. • Installation methods a single phase mixed circuits. • correct operation of the installed circuits including testing for correct compliance with Australian Standards.

Student Activity	Done	
Read **Wiring and cabling systems** Electrical Wiring Practice (7th ed.) Vol.1 Page 171 to 187		



A mixed circuit with a combination of socket outlets, lighting points, smoke detectors, exhaust fans is permissible and guidance to the loading of circuits is given in section C5 of appendix C. Table C9, 'Number of points connected to circuits', gives a current allocation to items like socket outlets and lighting points. The total of this allocation is not to exceed the nominal rating of the circuit breaker.

TABLE C8

GUIDANCE ON THE LOADING OF POINTS PER FINAL SUBCIRCUIT

Cable cross-sectional area[a] (mm²)	Rating of circuit-breaker[a] (A)	Contribution of each point (A) (sum must not exceed rating of circuit-breaker)						Maximum connected load for a range[de] (W)
		Lighting points[f]	10 A single or multiphase socket-outlets[cghi]		15 A single or multi-phase socket-outlets[hi]	20 A single or multi-phase socket-outlets[hi]	Permanently connected fixed or stationary appliances[d] or water heaters	
			Non-domestic installations without permanent airconditioning	All domestic installations and non-domestic installations with permanent airconditioning				

Mixed circuits of lighting points, smoke detectors and exhaust fans is a common electrical installation practice.
Mixed circuits of socket outlets and lighting points are common in sheds garages and small domestic outbuilding.

Segregation of circuits
Section 1.6.5 of the AS/NZS3000 wiring requires that all electrical installations are required to be divided into circuits to avoid danger, minimise inconvenience if a fault was to occur. This means that the operation of a circuit breaker due to a fault does not leave the owner of the installation without alternative lighting or socket outlets.
This segregation also provides for safe operation of circuits and the facilitation of inspection, testing and maintenance.

Section 3.9.8.3 requires segregation of cables of low voltage and extra low voltage circuits in wiring systems unless the low voltage cable are double insulated or each conductor in a multi-core cable is rated for the highest voltage or barriers are used in a trunking system.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Work Sheet 4C - 1**	**Revised 07/2014 UEENEEG033A**

Answer the following questions

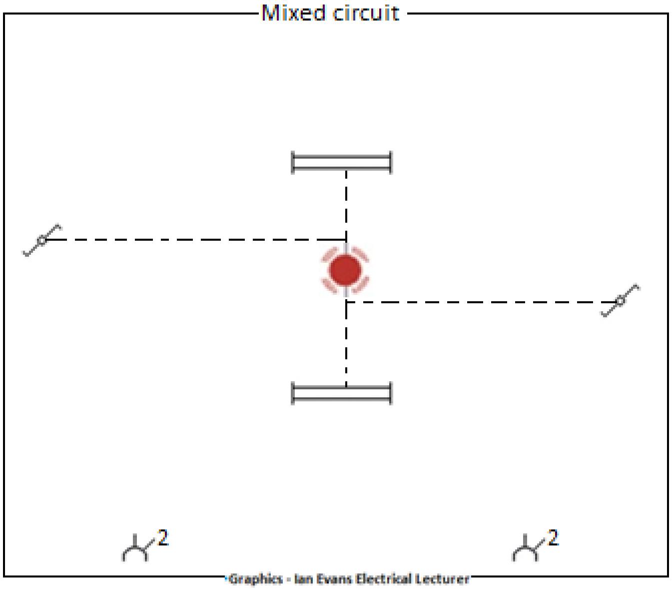
1. Describe the purpose of a mixed circuit.

2. What table in the AS/NZS3000 wiring rules provides guidance on circuit loading for a mixed circuit?

3. Why does the AS/NZS3000 wiring rules require that circuits in an electrical installation be segregated?

4. Describe the procedure for ensuring the correct operation of the following installed mixed circuit.

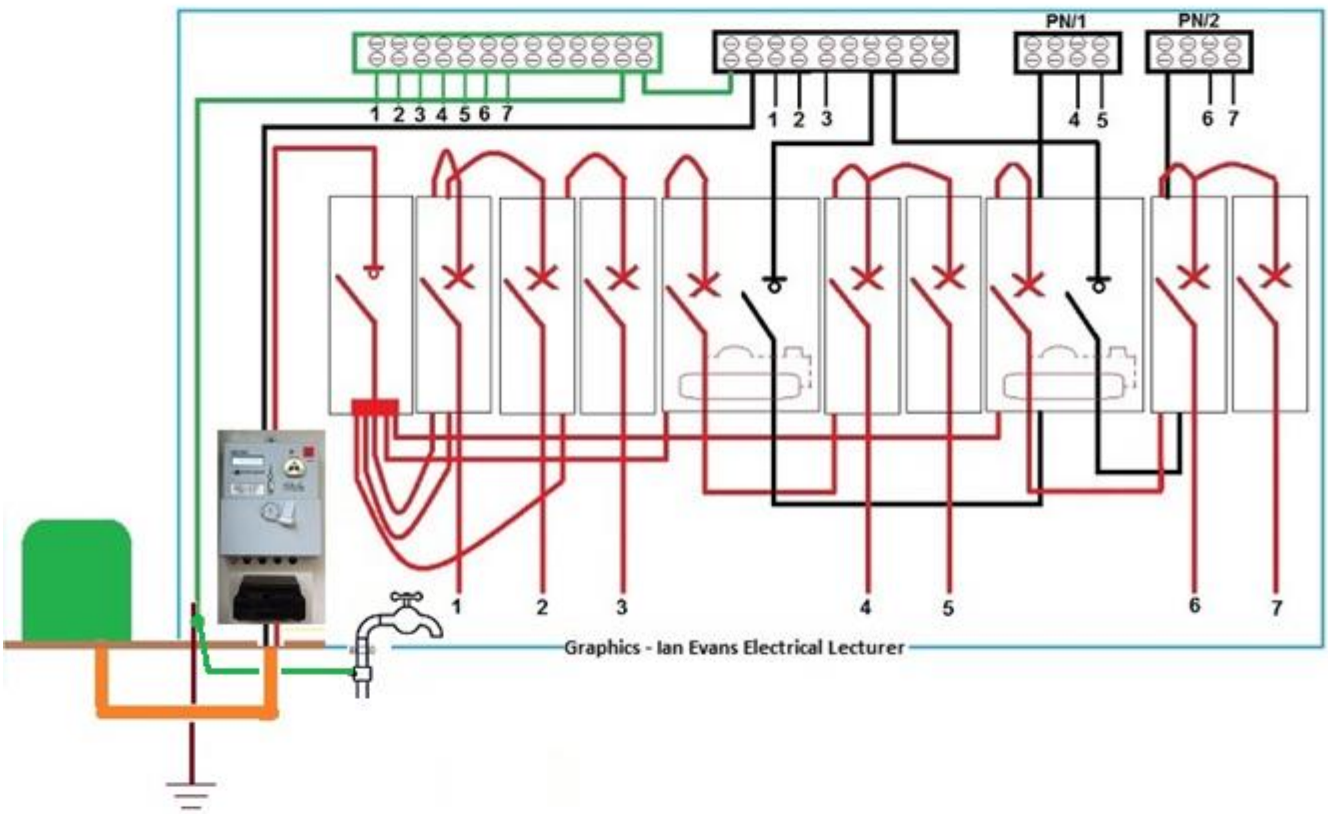
5. Describe the procedure for ensuring the correct testing for correct compliance with Australian Standards of the following installed mixed circuit.



Circuit supplied from the main switchboard. 2.5 mm^2 TPS flat protected by a 16 A C type circuit breaker.

Government of Western Australia North Metropolitan TAFE	**Solve problems in single and three phase low voltage electrical apparatus and circuits**	**Installation Activity 4D - 1**	**Revised 07/2014** **UEENEEG033A**

Student Activity	**Done**	
Review **Chapter 7 Wiring and cabling systems** in Electrical Wiring Practice Volume 1 (7thEd) Pages 171 to 217		
Review **Chapter 8 Protection – earthing and protective measures** Electrical Wiring Practice Volume 1 (7thEd) Pages 221 to 247		
Review **Chapter 9 Testing techniques and compliance verification** in Electrical Wiring Practice Volume 1 (7thEd) Pages 251 to 284		
Review AS/NZS 3000:2018 Section 5 (Earthing)		
Install and Test a Domestic installation		



Install and Test a Domestic installation

All tasks in the installation must be compliant with AS/NZS 3000:2018, AS/NZS 3008, WAER 2014 and any other appropriate regulations.
The installation condition is partially surrounded by thermal insulation. (ie within 100mm of the ceiling)
To prove competence in this Unit (G0033A) all tasks must be successfully completed.

Task 1 - LIGHTING
Wire an appropriate TPS cable from the DB to L1. L1 is to be controlled via two-way switching system by SW1 and SW2. The lighting system must incorporate **looping at the light.**

Task 2 - EXHAUST FAN
Wire an appropriate TPS cable from L1 to an exhaust fan.
The Fan is to be controlled by SW 3.

Task 3 - MIXED CIRCUIT
Wire an appropriate TPS cable from the DB to a power outlets, SO3 and SO 4, and a lighting point, L 2. The Lighting point is to be controlled by SW 4.

Task 4 - POWER
Wire an appropriate TPS cable from the DB to power outlets SO 1 and SO 2

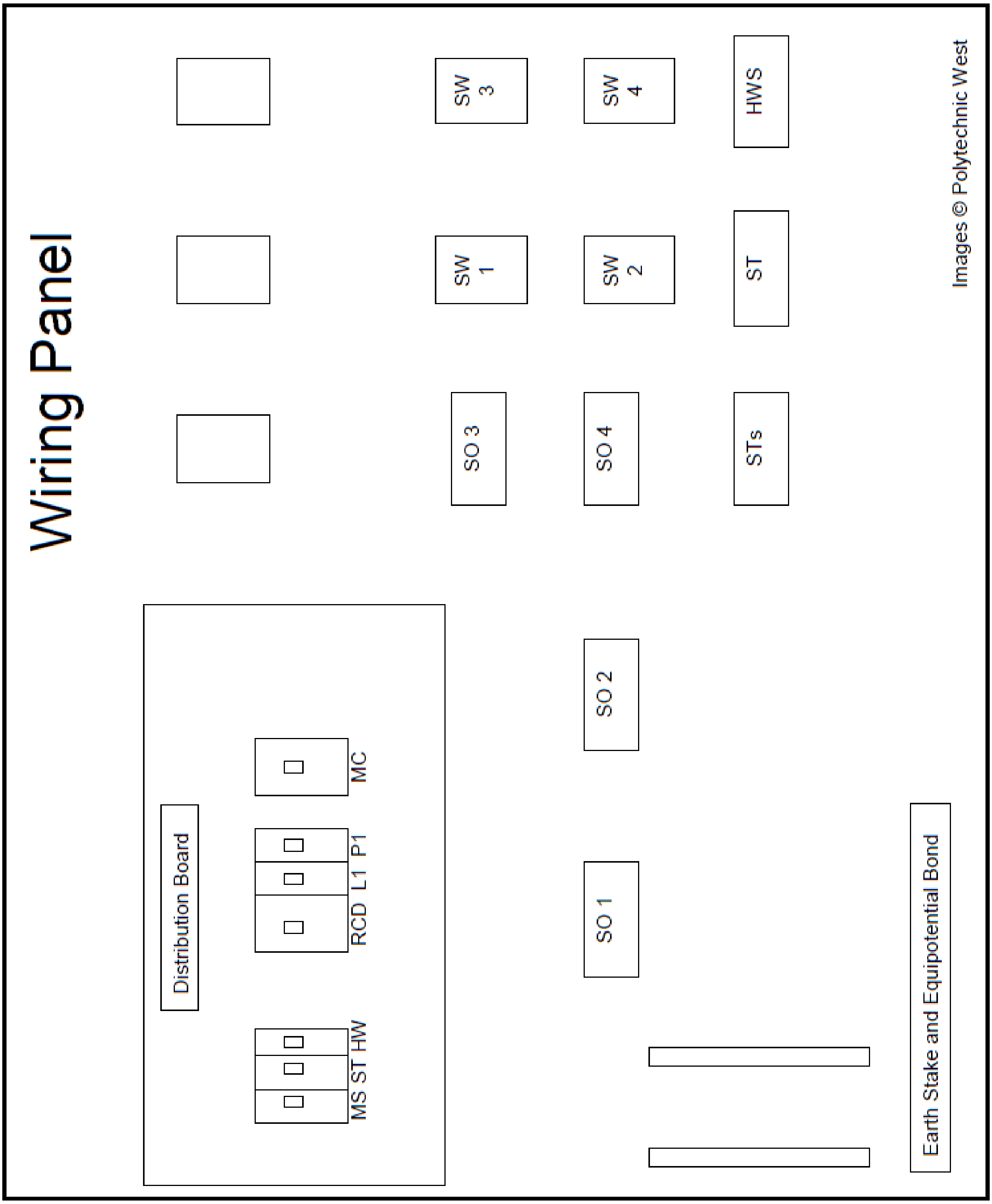
Task 5 - COOKING RANGE
Wire an appropriate TPS cable from the DB to the cooking range. The cooking range is rated at 8.2kW and has an open cooking surface.

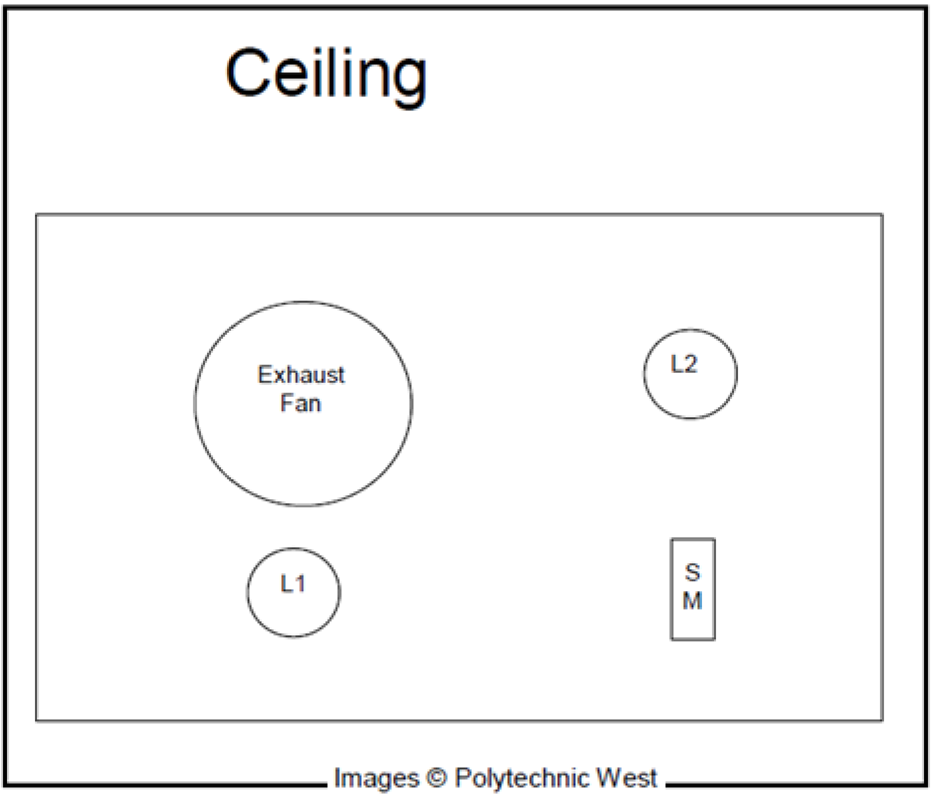
Task 6 - HOT WATER SYSTEM
Wire an appropriate TPS cable from the DB to the Hot Water Service. The Hot Water Service is rated at 3.6kW.

Task 7 - SMOKE DETECTOR
Install a smoke detector in accordance with the AS/NZS 3000 2018 (Wiring Rules) and local requirements

Task 8 - TERMINATE SWITCHBOARD
Connect all final sub circuit to the appropriate protective devices and links. Connect the internal wiring of the switchboard.

Task 9 - TEST INSTALLATION
Test the whole installation in accordance with Section 8 of AS 3000 Wiring Rules and record ALL results
NOTE:
The lighting and the power circuits will be protected by Residual Current Devices.
The mixed circuit will be protected by an RCD/CB combination.
Appropriate Circuit Breakers must be installed.


Wiring Panel
SW 3
SW 4
HWS
SW 1
SW 2
ST
SO 3
SO 4
STs
Images © Polytechnic West
Distribution Board
MC
RCD L1 P1
MS ST HW
SO 2
SO 1
Earth Stake and Equipotential Bond



Legend

SO = Socket Outlet | S = Switch | ST = Stove | STs = Stove Isolator

HW = Hot Water System | L = Light Point | SM = Smoke Detector

M = Main Switch | MC = RCD Combination (Mixed Circuit)

1. Generate a materials list for the Project

Manufacturer	Catalogue No	Description	Quantity
Clipsal	413	Fan socket	1
Olex		2.5 mm^2 TPS Cable HWS	5 metres

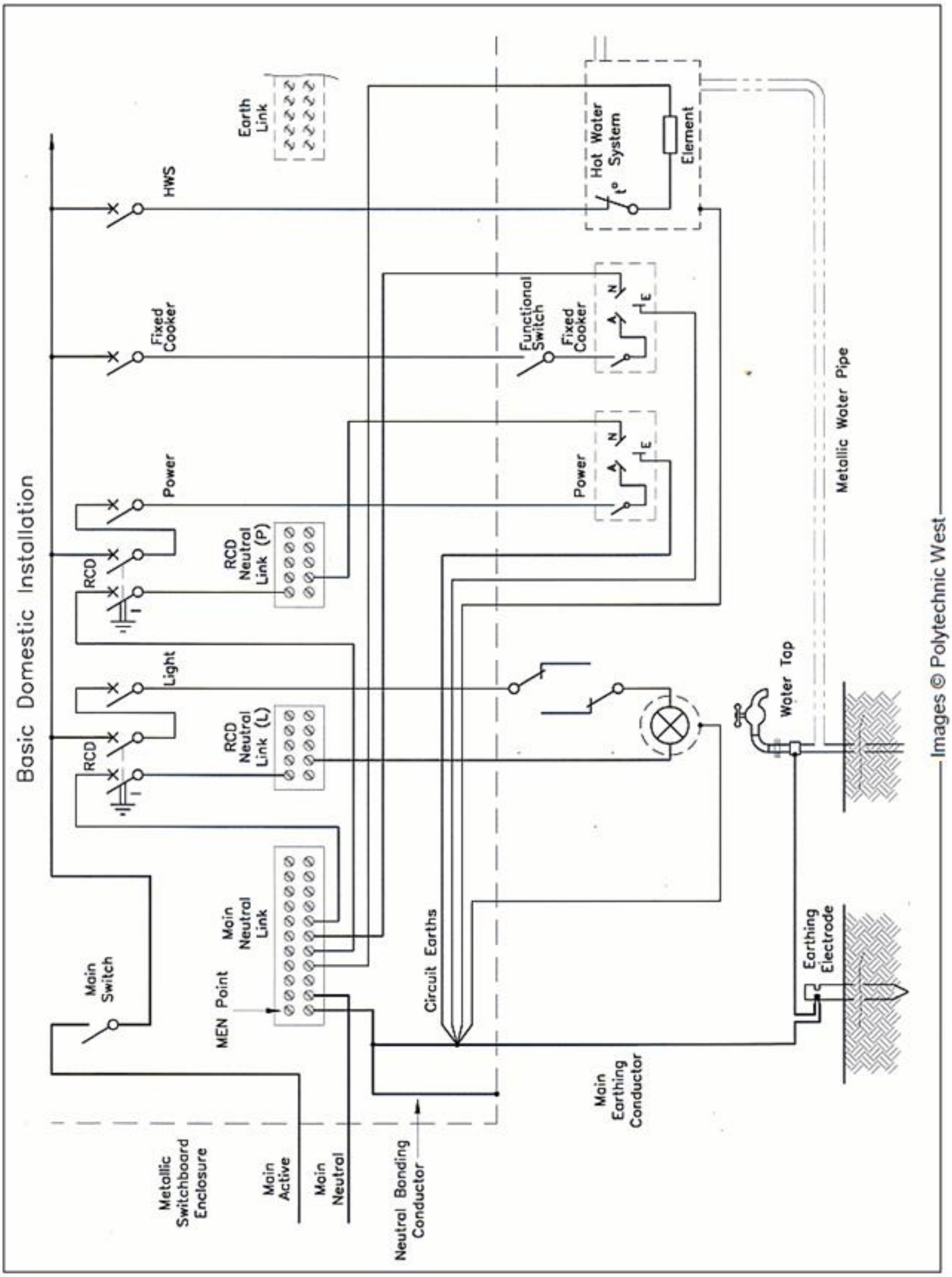
2. What is the current rating of the circuit protective device required for the cooking appliance?

3. What is the minimum size cable required for the stove cable?

4. What is the minimum size TPS cable that can be used to wire the lighting component of the mixed circuit?

5. What type of wiring system is used for the internal wiring of the switchboard?

6. Which regulation/code determines that require smoke detectors to be installed in a domestic dwelling?


Basic Domestic Installation
Earth Link
HWS
Fixed Cooker
Power
Light
RCD
RCD
RCD Neutral Link (P)
RCD Neutral Link (L)
Main Neutral Link
MEN Point
Main Switch
Circuit Earths
Hot Water System
Element
Functional Switch
Fixed Cooker
Power
Metallic Water Pipe
Water Tap
Earthing Electrode
Main Earthing Conductor
Metallic Switchboard Enclosure
Main Active
Main Neutral
Neutral Bonding Conductor
Images © Polytechnic West

Sample Electrical Safety Certificate

Department of Consumer and Employment Protection
EnergySafety

Form authorised by the Director of Energy Safety – Issued July 2008

Certificate number AA 001

ELECTRICAL SAFETY CERTIFICATE

Electricity (Licensing) Regulations 1991, Regulation 52B

This certificate warrants that the electrical installing work described below is safe and complies with the *Electricity (Licensing) Regulations 1991*.

This Electrical Safety Certificate is the certificate of compliance referred to in Regulation 52B of the *Electricity (Licensing) Regulations 1991*. This regulation requires that the electrical contractor/authorised* electrician completing electrical installing work must, within 28 days of completing the work, provide a certificate of compliance in respect of the work to the person for whom the work was carried out.

Installation details

Owner/Occupier Name		Meter No.	
Address			
New Installation (Y/N)		Alteration/Addition (Y/N)	
Date of Completion			

Details of work completed (indicate a number/rating where relevant)

General description of the work:

The following detailed information MUST ALSO be provided – indicate the number or rating in each category

Lights		Water Heaters	
Socket Outlets		Motors	
Cooking Appliances		Air Conditioners	

Details of any defects observed (alterations and additions only)

Certification by authorised* electrician who completed the work

I certify that the electrical installing work that is subject of this certificate has been completed, checked and tested and, at the time of testing, met the requirements of the *Electricity (Licensing) Regulations 1991* and is safe.

Name (please print)	
Signature	
Licence No.	EW

Details of electrical contractor

Licence No.	EC
Business Name	
Business Address	
Phone No.	
Facsimile No.	

Date

* Authorised pursuant to Regulation 52B(5) of the *Electricity (Licensing) Regulations 1991*

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Energy Safety
http://www.commerce.wa.gov.au/energysafety

Notes: