SFEU

Scottish Further Education Unit

Skills for Work: **Engineering Skills Intermediate 2**

Electrical and Electronic

Support Material

June 2008

Scotland's Colleges

Acknowledgements

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Engineering Skills: Electrical and Electronic (Intermediate 2)
F 39C 11

Introduction

These notes are provided to support teachers and lecturers presenting the Scottish Qualifications Authority Unit F39C 11, *Engineering Skills: Electrical and Electronic (Intermediate 2)*.

Enquiries relating to this support pack or issues relating to copyright should be addressed to:

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Website: www.sfeu.ac.uk

Further information regarding this Unit including Unit Specifications, National Assessment Bank materials, Centre Approval and certification can be obtained from:

The Scottish Qualifications Authority
Optima Building
58 Robertson Street
Glasgow
G2 8DQ

Website: www.sqa.org.uk

Class Sets

Class sets of this pack may be purchased direct from the printer. Costs are dependent on the size of the pack and the number of copies. Please contact:

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Disclaimer

Whilst every effort has been made to ensure the accuracy of this support pack, teachers and lecturers should satisfy themselves that the information passed to candidates is accurate and in accordance with the current SQA arrangements documents. SFEU will accept no responsibility for any consequences deriving either directly or indirectly from the use of this pack.

Contents

How to Use this Pack

None of the material in this pack is mandatory. Rather, it is intended as a guide and an aid to delivery of the Unit and aims to provide centres with a flexible set of materials and activities which can be selected, adapted and used in whatever way suits individual circumstances. It may also be a useful supplement to tried and tested materials and approaches that you have developed yourself. The pack is available on the SFEU website in Word format to enable you to customise it to your suit your own needs.

The **Reference Section** of the pack provides information on the rationale for, and ethos behind, the *Skills for Work* courses, the course rationale, and the Employability Skills Profile for Intermediate 2 Engineering showing where the specified employability skills and attitudes can be evidenced and assessed throughout the Course and in this Electrical and Electronic unit.

The **Tutor Support Section** contains a suggested approach to teaching the Unit; advice on learning and teaching with under-16s; guidance on unit induction, unit delivery, Health and Safety considerations and advice on integrating the development of employability skills throughout the unit. Finally, this section suggests resources which may be useful for tutors and students.

The **Student Support Section** contains guidance and instruction on a range of student activities and workshop task sheets covering the practical outcomes of the Unit. It also contains detailed notes that cover the knowledge and understanding aspects of the Electrical and Electronic Unit followed by a Glossary of terms used in the support notes.

You may wish to place material from the student notes on your own college Intranet by downloading this pack from the *Skills for Work* section of the SFEU website www.sfeu.ac.uk/skills_for_work

Activities are identified with the symbol: 

Reference Section

What are Skills for Work Courses all about?

Skills for Work Courses are designed to help candidates to develop:

- skills and knowledge in a broad vocational area
- Core Skills
- an understanding of the workplace
- positive attitudes to learning
- skills and attitudes for employability.

A key feature of these Courses is the emphasis on **experiential learning**. This means learning through practical experience and learning by reflecting on experience.

Learning through practical experience

Teaching/learning programmes should include some or all of the following:

- learning in real or simulated workplace settings
- learning through role play activities in vocational contexts
- carrying out case study work
- planning and carrying out practical tasks and assignments.

Learning through reflecting at all stages of the experience

Teaching/learning programmes should include some or all of the following:

- preparing and planning for the experience
- taking stock throughout the experience - reviewing and adapting as necessary
- reflecting after the activity has been completed - evaluating and identifying learning points.

The *Skills for Work* Courses are also designed to provide candidates with opportunities for developing **Core Skills** and enhancing skills and attitudes for **employability**.

Core Skills

The five Core Skills are:

- Communication
- Numeracy
- Information Technology
- Problem Solving
- Working with Others

Employability

The skills and attitudes for employability, including self-employment, are outlined below:

- **generic skills/attitudes valued by employers**
  - understanding of the workplace and the employee's responsibilities, for example time-keeping, appearance, customer care
  - self-evaluation skills
  - positive attitude to learning
  - flexible approaches to solving problems
  - adaptability and positive attitude to change
  - confidence to set goals, reflect and learn from experience.
- **specific vocational skills/knowledge**
  - Course Specifications highlight the links to National Occupational Standards in the vocational area and identify progression opportunities

Opportunities for developing these skills and attitudes are highlighted in each of the Course and Unit Specifications. These opportunities include giving young people direct access to workplace experiences or, through partnership arrangements, providing different learning environments and experiences which simulate aspects of the workplace. These experiences might include visits, visiting speakers, role play and other practical activities.

A Curriculum for Excellence (Scottish Executive 2004) identifies aspirations for every young person. These are that they should become:

- successful learners
- confident individuals
- responsible citizens
- effective contributors.

The learning environments, the focus on experiential learning and the opportunities to develop employability and Core Skills in these Courses contribute to meeting these aspirations.

The Course in Engineering Skills (Intermediate 2)

Course Rationale

The Engineering Skills (Intermediate 2) Course has been designed to provide a basis for progression into further education or for moving directly into training in employment within an engineering sector. The overall purpose of the Course is to ensure that candidates start to develop the generic and practical skills, knowledge and understanding, and employability skills needed within an engineering sector.

The engineering sector includes the following:

Mechanical	Manufacture	Maintenance
Fabrication	Welding	Electrical
Electronic	Foundry	Automotive
Control	Transport	Aeronautical
Communications	Space	Energy Generation
Conservation	Marine	Water
Desalination	Oil/Gas	Petroleum

This Course focuses on the broad areas of Mechanical, Fabrication, Electrical, Electronic, Maintenance, Manufacture, and an element of Design. This will allow the candidates to gain transferable skills which can be applied to any of the above engineering areas.

The primary target group for this Course is school candidates in S3 and above. It may be suitable for candidates entering engineering for the first time but also for those who have completed the Engineering Skills (Intermediate 1) Course. This Course will build on the skills and knowledge developed in the Engineering Skills (Intermediate 1) Course and will introduce candidates to a wider range of engineering applications.

It is anticipated that, for this group of candidates, the Course will rely on and build on existing partnerships between schools and colleges and employers (or other agencies). This may be particularly pertinent in the case of the Engineering Skills Course due to the specialist expertise and facilities available in, for example, further education colleges and training providers. Nevertheless, the Engineering Skills Course is designed at a level and scope such that it can be delivered in schools, if the school has suitable facilities and teaching expertise. A partnership approach would still be necessary in order to provide the contact with the workplace which is an essential part of the experience for candidates. The Course is also suitable for adult candidates who are seeking to enhance their employability and develop introductory vocational skills in an engineering sector.

The general aims of the Engineering Skills (Intermediate 2) Course are to:

- widen participation in vocationally-related learning for school candidates from S3 upwards
- allow candidates to experience vocationally-related learning
- provide candidates with a broad introduction to the engineering vocational sector
- encourage candidates to foster a good work ethic, including timekeeping, a positive attitude, and other relevant employability skills
- provide opportunities to develop a range of Core Skills in a vocational context
- encourage candidates to take charge of their own learning and development
- provide a range of teaching, learning, and assessment styles to motivate candidates to achieve their full potential
- facilitate progression to further education and/or training
- encourage candidates to plan their work and review their progress
- encourage candidates to develop a positive attitude to waste minimisation and environmental issues

In particular, the aims of the Engineering Skills (Intermediate 2) Course are to:

- encourage candidates to consider a career in the engineering industry
- develop an awareness of what opportunities there may be within engineering in terms of the types and range of career options
- enable candidates to develop and apply practical, technical, and communication skills as a foundation for future learning and progression
- develop the candidates' awareness of their individual strengths and weaknesses in relation to the requirements of engineering, and to reflect on how this affects their employability potential
- give candidates the technical knowledge, skills, and understanding associated with a range of skills in engineering at this level
- give candidates an introduction to the design cycle
- encourage candidates to apply their knowledge and understanding of engineering by using skills of evaluation and problem solving in a vocational context
- develop an awareness that health and safety issues are integral to the world of work generally and engineering in particular
- prepare candidates for further learning opportunities, study, and training for employment in engineering and related occupations

The Engineering Skills (Intermediate 2) Course has been designed with National Occupational Standards in mind. The standards set for first-year apprentices in the engineering industry, and the standards set out in the Intermediate 2 Course, are broadly comparable in terms of skills and tolerances.

While no formal entrance qualifications are required for this Course, it would be expected that candidates embarking on the Course would have the following:

- basic proficiency in literacy
- basic proficiency in numeracy
- some aptitude for graphical forms of communication (the reading of basic engineering drawings is developed in the Course)
- motivation to work as part of a team

This Course supports progression into appropriate further education, training, or employment. The Course provides the basis for candidates to gain an insight into engineering occupations such as Mechanical, Fabrication, Automotive, Aeronautical, Electrical, and Electronic, Marine, Control, Maintenance, and Manufacture and to use their studies to help them decide the career they wish to follow. Candidates studying this Course in Engineering and choosing a skills option, may be aiming to progress into an apprenticeship in industry. Candidates who are uncertain which trade to follow may undertake vocational courses at further education colleges.

The Intermediate 2 Course should facilitate progression to a relevant vocational Course or an appropriate National Certificate/Qualification programme.

Unit Outcomes, PCs and Evidence Requirements

National Unit Specification: statement of standards

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit Specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Identify, select, and use a range of tools to terminate and test electrical cables and accessories.

Performance Criteria

a) Identify and state the use of cables and accessories used in electrical circuits correctly.
b) Identify and safely use tools correctly.
c) Terminate cables and accessories correctly.
d) Complete tests to ensure cable and accessory continuity and integrity.
e) Correctly observe safe working practices in all practical activities.

Outcome 2

Identify, select, and use a range of tools to terminate and test electronic cables and components.

Performance Criteria

a) Identify and state the use of cables and components used in electronic circuits correctly.
b) Identify and safely use tools correctly.
c) Terminate cables and components correctly.
d) Complete tests to ensure cable and component continuity and integrity.
e) Correctly observe safe working practices in all practical activities

Outcome 3

Construct and test circuits from given diagrams.

Performance Criteria

a) Construct an electrical circuit from given diagrams and specifications correctly.
b) Construct an electronic circuit from given diagrams and specifications correctly.
c) Complete a quality check to test and record each circuit function.
d) Correctly observe safe working practices in all practical activities.

Outcome 4

Review and evaluate own employability skills in practical engineering contexts.

Performance Criteria

a) Review and evaluate own employability skills.
b) Seek and record feedback on own performance in employability skills.
c) Make a judgement on own strengths, weaknesses and learning points in relation to employability skills.
d) Identify action points for improvement in relation to employability skills.

Evidence Requirements for the Unit

Performance evidence and written/oral evidence is required to show that all Outcomes and Performance Criteria have been achieved.

Performance evidence will be supported by assessor checklists. This evidence will be generated from an integrated assignment consisting of practical activities carried out in supervised workshop conditions.

The evidence may be gathered at different points throughout the Unit.

The practical activities in the preparation, planning, and construction of extra low voltage electrical and electronic circuits in a safe manner, which should conform to current legislation, will cover:

- interpretation of simple diagrams and specifications
- identification and use of the following electrical and electronic cables:
    - single core, multi core, twin and earth, screened, co-axial, and ribbon
- identification and use of the following electrical accessories:
    - consumer Unit, switches, lamp holders, sockets, and protective devices
- identification and use of the following electronic components:
    - resistors, capacitors, inductors, diodes, transistors, ICs, and audio/visual devices
- selection, function, and use of the following tools:
    - screwdrivers (various), wire strippers, wire cutters, pliers, crimping tool, solder irons, circuit assembly aids, and digital test instruments

The electrical circuit will be constructed:

- using any cable(s)
- using at least three different types of accessory
- using four tools

The electronic circuit will be constructed:

- using any cable(s)
- using at least four different types of component
- using four tools

The circuits should be tested using suitable test instruments and the results recorded.

Candidates will be required to carry out quality checks before submitting their work for final assessment.

Written/Oral Evidence

Candidates will complete a self evaluation review of their own performance against the following employability skills:

- maintaining good timekeeping and attendance
- showing health and safety awareness — to include wearing Personal Protective Equipment (PPE), safe working practices and understanding a basic risk assessment
- selecting and using engineering tools and materials — source and use tools in a correct and safe manner, use tools solely for the purpose for which they are designed and selection of engineering materials
- interpreting engineering drawings and specifications
- awareness of environmental considerations — to include safe and correct disposal of waste/hazardous materials, waste minimisation and fume and dust control
- quality checking own work
- self review and evaluation — to include identifying strengths and weaknesses, identifying learning points from practical experiences and having a positive attitude to learning

A signed record of the review must be retained by the assessor as assessment evidence.

The National Assessment Bank (NAB) item for this Unit provides an appropriate practical assignment, an appropriate candidate review sheet and assessor checklists. These exemplify the national standard. Centres wishing to develop their own assessments should refer to the NAB to ensure a comparable standard.

NB Centres must refer to the full Unit Specification for detailed information related to this Unit.

Employability Skills Profile

In addition to the specific, vocational skills developed and assessed in this Course, employability skills are addressed as detailed in the table below. For the purposes of the table, the Units are referred to as A, B, C and D as indicated.

Engineering Skills (Intermediate 2)

Mechanical and Fabrication	**=**	**A**
Electrical and Electronic	**=**	**B**
Maintenance	**=**	**C**
Design and Manufacture	**=**	**D**

Employability skills/attitude	Evidence
• maintaining good timekeeping and attendance	A, B
• showing health and safety awareness	A, B, C, D
• selecting and using engineering tools and materials	A, B
• interpreting engineering drawings and specifications	B, C, D
• working cooperatively with others	C, D
• planning and preparing for work	C, D
• applying time management	D
• awareness of environmental considerations	B, C
• quality checking own work	A, B, C, D
• self review and evaluation	A, B, C, D

Assessment evidence in all Units:

Assessor observation checklists of practical activities and candidate review sheets.

Careers Scotland Support
for School-College Collaboration for Scotland's Colleges in the Scottish Enterprise area

Since August 2006 Careers Scotland (SE and HI areas) has been funded by the Scottish Government to support College/School Collaboration and encourage and promote vocational educational choices for pupils in schools.

Careers Scotland (now part of Skills Development Scotland) has an important role to play in selection, recruitment and pre-entry career guidance, as well as ongoing support and pre-exit career guidance, to ensure the pupils' experience of SfW is capitalised upon in any future career planning.

Careers Scotland activity takes place locally and nationally under 4 objectives:

- Providing careers advice, guidance and employability support to pupils and their parents pre, during and post vocational education experience, focusing primarily but not exclusively on SfW pupils - demonstrating how these educational choices have implications for future career options, and support the achievement of future career goals and supporting effective transitions
- Providing targeted support to pupils at risk of becoming unemployed who would benefit from undertaking a vocational course
- Partnership working to ensure vocational study is given parity of esteem with other school and post school options, focusing on recruitment / selection and retention of pupils on vocational courses
- Capacity building through relevant shared CPD events and resource development to increase understanding of the process of uptake of vocational options and facilitate more effective support to pupils navigating these options

For further information on Careers Scotland (SE)'s involvement in school/college collaboration locally, please get in touch with your Careers Scotland Regional contact:

South East	(Edinburgh & Lothians; Forth Valley; Borders)
Stephen Benwell	01786 452043 stephen.benwell@careers-scotland.org.uk
North East	(Tayside; Grampian; Fife)
Val Ormiston	01592-631155 valerie.ormiston@careers-scotland.org.uk
South West	(Dumfries & Galloway; Ayrshire; Lanarkshire)
Jean Geddes	01698 742192 jean.geddes@careers-scotland.org.uk
West	(Glasgow; Dunbartonshire; Renfrewshire)
Sandra Cheyne	0141 242 8338 sandra.cheyne@careers-scotland.org.uk

Tutor Support Section

Introduction

The main purpose of this Unit is to enable students to select the correct tools and components required to construct a basic functional extra low voltage electrical circuit and an electronic circuit from a given diagrams and specifications. The unit is designed to be both electrical and electronic. The local industries and workshop facilities might be the deciding factor in the type of circuitry selected.

The student will learn basic terminology and skills during the process of the practical work. The student will also develop work practices and attitudes that will enhance their employability skills.

Students who have completed the *Engineering Skills: Intermediate 1* course will have developed both practical and employability skills appropriate to that level of course. The *Engineering Skills: Intermediate 2* course will further enhance and develop the practical and employability skills at this level.

The need to promote safe working practices in the electrical/electronic workshop with respect to industry is paramount at all times.

Safe working practices should include:

- Electrical safety
- Keeping the work place tidy and free from obstruction
- Maintaining good working relationships with others
- Maintaining a positive attitude to instruction
- Care and use of tools
- Being appropriately dressed for workshop activities
- Wearing the relevant Personal Protective Equipment (PPE)

As well as being taught the correct techniques for the interpretation of drawings and specifications, handling and using tools and materials, students should be given support in the development of all the practical and employability skills.

The time allocations for each Outcome are intended as a guide only. The actual time spent on each Outcome will depend on the ability and prior experience of the student.

The Outcomes in this Unit are practical and students should be given ample of opportunity to handle and work with tools and equipment relevant to electrical and electronic work. The building of student confidence is a vital and important part of the unit, so students should be given adequate support in all stages of practical work.

Additional Student Activities

There is a significant degree of similarity between the Intermediate 1 Engineering Skills: Electrical/Electronic Unit and the Intermediate 2 Engineering Skills: Electrical and Electronic Unit.

This means that the handout materials and task types in this Intermediate 2 This means that the handout materials and task types in this Intermediate 2 Engineering Skills: Electrical and Electronic support pack are similar to those of the Intermediate 1 Engineering Skills: Electrical/Electronic support pack, although the outputs will be required to demonstrate a higher skill level. The overlap in pack content is necessary however, for use with students who have not progressed through the Intermediate 1 route.

Students who have previously completed the practical activities of the Intermediate 1 Engineering Skills: Electrical/Electronic unit will nevertheless require additional activities to allow them to apply their developing skills in new contexts.

These additional activities are found at the end of this Student Support Section.

Learning and Teaching with Under 16s

Scotland's Colleges have made significant progress in meeting the needs of young learners. Our knowledge of the learning process has increased significantly and provides a range of strategies and approaches which gives us a clear steer on how lecturers can add to their skill repertoire. Lecturers can, and do, provide a stable learning environment where young students develop a sense of self-respect, learn from appropriate role models and see an opportunity to progress. There are basic enabling skills for practical application which can further develop the learning process for this group of students. So what are the characteristics of effective learning and teaching which will help to engage young learners?

Ten ways to improve the learning process for under 16s
(This list is not exhaustive!)

1. **Activate prior knowledge and learning** – ascertain what the learner knows already and teach accordingly. Young people do have life experience but it is more limited than adult learners and they may not always be aware of how it will assist them in their current learning.

   Tips - Question and answer; Quick Quiz; Quick diagnostic assessment on computer; present key words from the course or unit and see how many they recognise or know something about.

2. **Tune learners into the Big Picture** – the tutor knows the curriculum inside out and why each lesson follows a sequence, however the young learner does not have this information and is re-assured by being given the Big Picture.

   Tips – Mind map or concept map; use visuals, for example wall displays of diagrams, photographs, flow charts; explain the learning outcomes in language they will understand; We Are Learning Today (WALT) targets and What I'm Looking For (WILF) targets; give clear and visible success criteria for tasks.

3. **Use Advance Organisers** – these are lists of the key concept words that are part of the course or unit.

   Tip – Highlight on any text the concept words that you will be using; make a visible list and put it on display – concept words can be struck off or referred to as they occur (NB this helps with spelling and independent learning as they do not have to keep checking meaning); highlight essential learning and action points.

4. **Vary the teaching approaches**. The two main approaches are instructing and demonstrating, however try to provide opportunities to facilitate learning.

   Tips – Ask students what they know now that they did not know before, or what they can do now they could not do before, at appropriate points in the lesson or teaching block; ensure there are problem solving activities that can be done individually or in groups; ask students to demonstrate what they have learned; use a range of question and answer techniques that allow participation and dialogue, eg. provide hints and cues so that they can arrive at answers themselves.

5. **Preview and review of learning**. This helps to embed previous learning and listening skills and provides another opportunity to elicit learner understanding. Consolidates and reinforces learning.

   Tips – At the beginning of each lesson, or session, review previous learning and preview what is coming up; at the end of each lesson or session, review what has taken place and what will be focussed on next time – these can both be done through question and answer, quizzes and mind mapping activities.

6. **Language in the learning environment**. Do not assume that the language which is used in the learning environment is always understood by young learners, some words may be familiar but do not have the same meaning when used vocationally.

   Tips - At appropriate points ask students what words mean; explore the various meanings of words to find out if they may have come across this language in another context; by looking at the structure and meaning of words there is an opportunity for dialogue about learning and to build vocabulary.

7. **Giving instructions in the learning environment**. This is one of the most difficult tasks a tutor has to do whatever the curriculum area. With young learners this may have to be repeated several times.

   Tips – Ask a student to repeat back what you have asked them to do before beginning a task; ask them to explain the task to one of their peers; use the KISS principle – Keep It Short and Simple so that they can absorb and process the information.

8. **Effective feedback**. Feedback is very important for the learner to assess their progress and to see how and what they can improve. Provide opportunities to engage in dialogue about the learning function of assessment – provide details of the learner's strengths and development needs either in written or spoken form. With younger learners identifying one or two areas for development is sufficient along with acknowledgement of what has been done well.

   Essentially, learners are helped by being given a **specific** explanation of how work can be improved. You can also use summative assessment formatively, ie. as an opportunity to identify strengths, development needs and how to improve.

   Tips – Ask students themselves to identify their own strengths and development needs – self evaluation; peer evaluation of work can be successful once they have been taught how to do it; the tutor can produce a piece of work and ask students to assess it anonymously; have a discussion about the success criteria for the task and ensure the students are clear about them; allow learners to set criteria for success and then measure their achievements against these.

9. **Managing the learning behaviour**. Under 16s are coming into Scotland's Colleges and training establishments from largely structured and routine-driven environments in schools and early feedback from those undertaking Skills for Work courses indicates that they very much enjoy the different learning environment that colleges and other training providers offer. Remember though that these are still young learners. They will still expect tutors to provide structure and routine, and will perform best in a calm, orderly learning environment. Young students will respond to firm, fair, and consistent management. Such routines have to be established quickly and constantly reinforced.

   Tips - Health and safety is non-negotiable and consequences of non-compliance with the regulations should be made clear and adhered to at all times; set out your expectations from day one and provide a consistent message; have clear beginnings, middles and endings for each session; be a positive role model for your students, ie. be there before they are and manage the learners with respect; always deliver what you promise; build up good relationships and get to know the learners, make the curriculum interesting and stress the relevance of the learning; set up a positive behaviour management system. By following these guidelines you will build up two-way respect, which, while sometimes challenging to achieve, can be very powerful and work to everyone's benefit.

10. **Care and welfare issues**. School/college partnerships mean increasing numbers of young learners in college. Tutors have to be aware of their professional responsibilities and mindful of young people's rights. However tutors have rights too, in terms of feeling safe and secure in working with young people and there are basic steps staff can take to minimise risks. It is essential that colleges ensure that tutors have a working knowledge of the Child Protection policies (local authority and college documentation) and follow procedures and policies diligently. School/College Liaison Officers will be familiar with these documents and can provide support and advice. There are also training sessions on Child Protection available from SFEU (see the following page).

    Tips - Avoid one-to-one situations with young students in a closed area; do not do or say anything that could be misinterpreted; if the opportunity arises, do some observation in schools to see and discuss how teachers use the guidelines for their own protection as well as the young person's.

Most young people are a delight to work with and they will positively enjoy the experience of learning in college. However, there will inevitably be some who are disengaged, disaffected and who have not yet had an opportunity to experience success. '*Skills for Work*' is a unique educational initiative that young people can be motivated to buy into – you as the tutor are key to the success of these programmes.

Skills for Work Workshops

To take this 10 point plan forward and to add to it, you can attend one of SFEU's *'Get Skilled Up'* half day workshops for tutors delivering *Skills for Work* Courses, when we explore further the learning process and look at a range of specific teaching and learning techniques to use with the under 16 age group. To find out when the next event is visit our website www.sfeu.ac.uk or contact the Learning Process team at SFEU on 01786 892000.

Child Protection Workshops

These are run on a regular basis by staff at SFEU in Stirling and also in colleges. For more information on these workshops please contact members of the Access and Inclusion team at www.sfeu.ac.uk or contact the team at SFEU on 01786 892000.

General Guidance on Unit Delivery

The emphasis in this unit is on a practical approach in which the students complete practical tasks. The unit is also designed to focus on the employability skills that employer's value.

The Unit should be delivered in an electrical/electronic workshop environment with students being appropriately dressed. At the start and finish of each practical activity, Health and Safety should be emphasised. Students should wear overalls, safety footwear and other PPE (Personal Protective Equipment) as required in the workshop. They should be made aware that employability skills such as attendance, punctuality, working with others, seeking advice and reviewing their progress will also be developed, supported and monitored. It is important that students evaluate their progress with employability skills and at the same time start to evaluate their practical skill development and state what they were good at and what they were not so good at.

As students progress through the practical activities, it is envisaged that opportunities will arise to discuss employability skills development and perhaps subsequent career paths. There should be adequate time to progress electrical and electronic engineering skills whilst at the same time giving each student a good insight to electrical and electronic engineering both locally and nationally.

Electrical and electronic engineering skills to be developed include:

- safe working practices/electrical safety
- commonly used terminology
- comprehension of drawings/diagrams
- names and use of tools
- cable and accessory types (electrical)
- cable and accessory termination/connection (electrical)
- cable and component types (electronic)
- cable and component termination/connection (electronic)
- electrical circuit construction - electronic circuit construction
- functional and continuity circuit tests

This Unit may be integrated for delivery with other units of the course. This approach will be at the delivering centre's discretion and will result in this support pack being used in conjunction with that of other units.

Core Skills Development

The unit is also an ideal opportunity to progress Core Skills within the context of electrical and electronic engineering:

- **Numeracy Skills**: in the form of measuring and cutting cables.

- **Working with Others**: is a valid and inherent skill in any workplace or workshop, and students should be actively encouraged to seek advice from their tutor whilst working with their peers as part of a team.

- **Problem Solving**: electrical/electronic engineering is beset with problems and trades people are faced on a daily basis with problems that require efficient and cost effective solutions.

- **Communication**: is part and parcel of the electrical/electronic engineer's working life, whether taking in oral or written instructions, asking questions to determine fault diagnosis, sketches and interpretation of drawings, interpretation of manufacturer's manuals, making an oral presentation or simply giving instructions to others.

- **IT**: is linked to all of the above. Most electrical/electronic engineers use IT to aid numeracy skills, to communicate and to problem solve. IT is used to present and record information, such as circuit test results. IT is also used to provide graphic communication for electrical/electronic engineers used to provide graphic communication for electrical and electronic engineers.

Unit Induction

An induction session in week 1 will prepare students well for the unit and help to clarify aims and expectations, what the unit is all about and any uncertainties they may have about the unit and how it will be delivered.

It's important to stress that the *Engineering Skills (Intermediate 2)* Course is predominantly practical so vocational and employability skills will be developed at the same time.

Induction may include the following:

- an outline of the Unit content – what they're going to be doing
- how it fits in to *Engineering Skills* Course
- your plans for teaching the Electrical and Electronics Unit - how they'll be learning the practical skills
- how they'll be assessed
- where employability fits in – start by asking them what they think!
- a section on health and safety
- an introduction to the concept of risk assessment in electrical and electronic engineering
- a practical electrical or electronic engineering activity
- the importance of regular attendance and good timekeeping to encourage employability skills development - get them into good habits – as if they were at work and in employment!
- you might also think about inviting an electrical or electronic engineer or both, to speak to the class about their work, about job prospects in the electrical and electronic engineering industry and to reinforce the value that employers put on employability skills

Health and Safety - Note

Students need to understand their roles and responsibilities in relation to health and safety. Students may already have an appreciation of health and safety issues in one of the other course units but it should be pointed out to them that in the electrical and electronic engineering industry we are dealing with a different set of potential hazards and that each practical activity will probably start and end with health and safety issues relevant to the lesson practical skill.

Scheme of Work

In the Electrical and Electronic Unit students will select the correct tools and components required to construct a basic functional extra low voltage electrical circuit and an electronic circuit from given diagrams and specifications. The electrical and electronic unit is designed to be both electrical and electronic. The local industries and workshop facilities might be the deciding factor but time allocated and the candidate base may also be a factor in the type of circuitry selected. Circuit simulation and/or circuit construction software can be used if available to help support the student with more complex circuit construction and component layout.

At the beginning and throughout each Outcome of the Unit the following should be emphasised and adhered to:

Safe Working Practices in the Workshop	**The Care and Use of PPE**
• Workshop safe working practices • Workshop housekeeping • Electrical safety • Accident procedures • Fire alarm procedures	• footwear • overalls • eye protection • hand protection

The first three outcomes should be taught in order with Outcome 4 integrated throughout all the practical activities.

Outcome 1 (approximately 10 hours)

Identify, select and use a range of tools to terminate and test electrical cables and accessories

Identify, select and use electrical cables and state a reason for the use of each	• single core • multi core • twin and earth
Identify, select and use electrical accessories and state a reason for the use of each	• consumer unit • switches • lamp holders • sockets • protective device
Select and safely use hand tools correctly	• screwdrivers (various) • wire strippers • wire cutters • pliers (various) • crimping tool • test instruments
Terminate and continuity test electrical cables and accessories	• clamp – crimp - connect • cables – accessories – terminal strip
Complete a quality check to ensure cable continuity and integrity	• no damage to cable insulation • no damage to conductor • no damage to accessories • accessories fitted correctly • accessories connected correctly • terminations tight • accessories and cables: terminations have continuity
Observe safe working practices	

Outcome 2 (approximately 10 hours)

Identify, select and use a range of tools to terminate and test electronic cables and accessories

Identify, select and use electronic cables and state a reason for the use of each	• single core • multi core • screened • co-axial • ribbon
Identify, select and use electronic components and state a reason for the use of each	• resistors • capacitors • inductors • diodes • transistors • ICs • audio/visual devices
Select and safely use hand tools correctly	• screwdrivers (various) • wire strippers • wire cutters • pliers (various) • soldering irons • circuit assembly aids • test instruments
Terminate and continuity test electronic cables and accessories	• clamp – solder • cables and components
Complete a quality check to ensure cable continuity and integrity	• no damage to cable insulation • no damage to conductor • no damage to components • components fitted correctly • connections tight • cables – components: terminations have continuity
Observe safe working practices	

Outcome 3 (approximately 15 hours)

Construct and test circuits from given diagrams

Use different electrical accessories (3 required)	• consumer unit • switches • lamp holders • sockets • protective devices
Use tools (4 required)	• screwdrivers (various) • wire strippers • wire cutters • pliers (various) • soldering irons • circuit assembly aids • test instruments
Use different electronic components (4 required)	• resistors • capacitors • inductors • diodes • transistors • ICs • audio/visual devices
Complete a quality check to test and record the circuit function	• electrical circuit function tested • electronic circuit function tested • electrical circuit continuity tested • electronic circuit continuity tested • electrical circuit results recorded • electronic circuit results recorded
Observe safe working practices	

Outcome 4 (approximately 5 hours)

Review and evaluate own employability skills in practical engineering contexts

Review and evaluate own employability skills Seek and record feedback on own performance in employability skills Make a judgement on own strengths, weaknesses and learning points in relation to employability skills Identify action points for improvement in relation to employability skills	Students will complete a Review Sheet covering: • maintaining good timekeeping and attendance • showing health and safety awareness • selecting and using engineering tools and materials • interpreting engineering drawings and specifications • awareness of environmental considerations • quality checking own work • self review and evaluation

Health and Safety Considerations

General safety in the workplace

This deals with the issues of:

- General Health and Safety
- Personal Protective Equipment (PPE)
- Safe working techniques (including tool-handling)
- Electrical Safety
- First Aid
- Fire Alarm
- COSHH
- Good housekeeping in the working environment

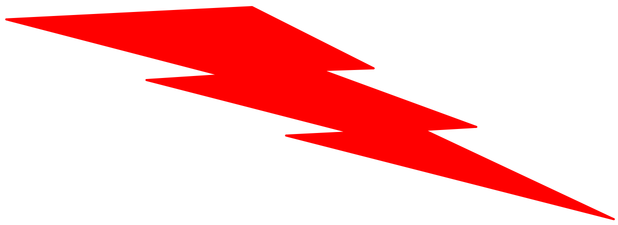
Each student will require the minimum **PPE** of safety boots and overalls for most workshop activities. In some cases students may require additional equipment such as goggles, gloves, safety spectacles or ear defenders.

Safe working techniques will include general workshop behaviour and protocol. This will include the correct handling and transportation of tools; tool safety; workshop layout; and procedures for starting and finishing practical activities.

An awareness and adherence to **electrical safety** should eliminate the dangers of electric shock or burns and the danger of fire. About 1000 accidents concerning electric shock or burns are reported to the Health and Safety Executive every year.

Many of these accidents can be avoided by common sense and a basic awareness of the causes.

Electrical safety must be observed at all times.



First Aid considerations should include nearest First Aid Station, First Aider, First Aid procedures, accident reporting and avoidance of potential accidents.

Fire alarm evacuation procedures should be practised and students made familiar with the audible warning sound, alarm points, location of fire fighting equipment, fire exits, assembly areas and correct conduct under alarm conditions.

The **Control of Substances Hazardous to Health (COSHH)** must be stressed if students are subjected or exposed to any chemicals, fumes, dust or irritants.

Good housekeeping is the welfare of all participants and the general working conditions in the workplace. This will include safety, PPE, behaviour, conduct, storage and condition of tools and equipment, walkways and handling and disposal of waste/scrap materials.

Whilst the tasks may not always require the movement or handling of heavy objects, the use of safety footwear and manual handling techniques should be discussed and encouraged as a matter of good safety practice.

Some tasks may require the use of heat or a heat source and students should be made aware of the dangers of both hot and previously heated materials and workbenches.

Personal Safety

The students must appreciate that they are responsible for their own safety and the safety of others. This will include their conduct and behaviour in all activities. Safe working practices in workshops and the safe use of tools and equipment should be emphasised.

In all the activities students are asked to perform they should be encouraged to make sound judgements on issues such as:

- the effect of their actions on fellow students
- are the tools and equipment in good usable condition?
- are they being asked to carry out an action they are unfamiliar with?
- should they seek advice from an appropriate person?

Students' personal dress should be hardwearing and give protection against grease/oil/heat etc. This clothing should not have any loose sleeves.

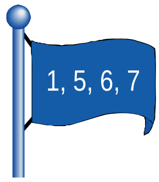
No jewellery of any form should be worn and neither should any piercings be worn.

Further information on Health and Safety can be found in the SFEU Publication '*Engineering Skills: Course Guidance and Employability Skills Intermediate 2*.

Signposting of Employability Skills

In addition to the specific vocational skills developed in this Unit, students will have opportunities to develop and apply their knowledge and understanding of the employability skills.

Throughout the pack there are numbered flags, like the one shown here, showing which specific employability skill can be highlighted and/or assessment evidence recorded when students are busy with the various activities in the Unit.



1	Maintaining good timekeeping and attendance*	6	Planning and preparing for work
2	Showing health and safety awareness*	7	Applying time management
3	Selecting and using engineering tools and materials*	8	Awareness of environmental considerations*
4	Interpreting engineering drawings and specifications*	9	Quality checking own work*
5	Working cooperatively with others	10	Self review and evaluation*

The employability skills marked with an asterisk* are directly assessed in this unit.

Generating Evidence and Assessment Opportunities for Employability Skills

The unit is designed around practical assignments which should enable the students to develop and apply practical, technical and communication skills as a foundation for future learning and progression. As instances arise naturally within the completion of practical work or activities, job roles and career paths may be discussed so that all students are aware of progressions within the engineering sector. These discussions will also encourage an interest in engineering in general.

It is envisaged that the development and recording of employability skills will be ongoing throughout the duration of each practical unit. It should be stressed at unit induction that skills valued by employers such as timekeeping, attendance etc will be monitored and recorded and that all students will be encouraged to show a positive attitude. Tutors should look for every opportunity to teach about the value of developing good employability skills as well as teaching trade specific skills.

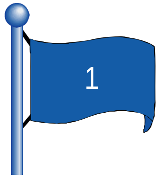
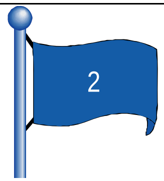
It is important that the students develop the ability to reflect on how they performed in the completion of tasks. In the context of this Electrical and Electronic unit this will involve reflection on the development of both practical and employability skills. The skill of evaluation lets the students analyse what they did well, what they did not do so well and how they can improve. This means they will develop an awareness of their individual strengths and weaknesses.

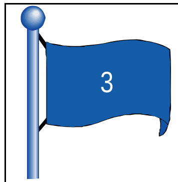
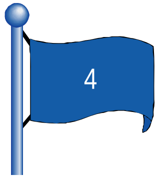
The unit also encourages the students to apply new skills, knowledge and understanding of engineering through the completion of practical assignments by using skills of evaluation and problem-solving in a vocational context.

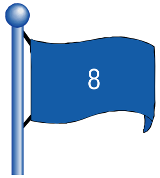
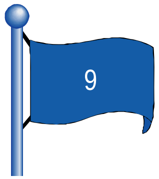
The following employability skills will be assessed in this unit. However, please note that it is expected that all the other employability skills are also developed throughout the unit.

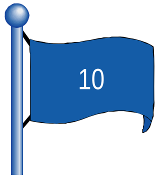
- maintaining good timekeeping and attendance
- showing health and safety awareness
- selecting and using engineering tools and materials
- interpreting engineering drawings and specifications
- awareness of environmental considerations
- quality checking own work
- self review and evaluation

You will find and create countless opportunities to help students develop their employability skills. Here are some to get you thinking:

Employability Skills	**Delivery Advice**	**Possible Activities/Contexts**
 **Maintaining good timekeeping and attendance**	Relate ground rules to the world of work, eg. arrive on time; back from breaks on time etc. Attendance and timekeeping should be monitored throughout the Unit. If you take note of patterns in performance it should be easy to give the students accurate feedback.	• turning up for class • returning from breaks • sticking to planned work schedules regarding timing of activities
 **Showing health and safety awareness**	Emphasise the importance of maintaining health and safety awareness – especially electrical safety in the context of this unit - at all times, of wearing appropriate PPE and the importance of **spotting** potential risks and hazards. This should lead to the application of Safe Working Practices – keeping walkways clear, correct manual handling techniques, tool and equipment safety etc.	• Discussion and activity on basic risk assessment to identify potential hazards in the workshop. • Group setting of guidelines on behaviour in the workshop. • Have groups identify potential hazards before each practical activity.

 **Selecting and using engineering tools and materials**	The correct use of tools must be demonstrated before students are allowed to practice the skill. Each tool has a function that it was designed for and use or misuse of the tool for any other task/purpose should be discouraged. Students should be encouraged to report any faulty or worn tools. Tools should always be returned to their proper storage place.	• Correct tools used • Carrying tools safely • Using tools safely • Clean and store tools safely and correctly
 **Interpreting engineering drawings and specifications**	Emphasise the importance of following drawings and specifications **accurately**. Tutors should take the opportunity in all tasks which involve using drawings to reinforce the importance of correct interpretation and of following instructions in the correct sequence.	• In small groups, give out a simple drawing and specification of an object. • Group discussion to interpret the drawing.

 **Awareness of environmental considerations**	Emphasise the importance of **awareness** of environmental consideration. Students should be encouraged to **think about** the need for environmental awareness - why they should save energy switch off lights, equipment and machinery etc.	Have students contribute to a workshop **environmental policy** that everyone adheres to. Form small groups and ask the students to find out themselves the correct disposal routes for waste materials.
 **Quality checking own work**	Emphasise the importance of **continually** checking as work progresses.	Students to be asked to verbally outline to other students if their work in progress is acceptable against specification, drawings and so on.

 **Self review and evaluation**	Encourage the students to genuinely **participate** in the self review and evaluation process. Individual and group discussions can help the students get into the habit of evaluating their performance as a natural part of their work routine.	• Conversations with tutor. • Quality checking. • Self evaluation exercises. • Students could be given a small reflective log book to record their learning from practical experiences.

More ways of helping you and your students can be found in the SFEU Publication '*Engineering Skills: Course Guidance and Employability Skills Intermediate 2*.

Resources

It is expected that this electrical and electronic unit will be taught in an experiential manner within a fully equipped, safe and suitably arranged electrical/electronic workshop. Resources required for individual lessons are set out in each lesson plan.

It is important that, as soldering may be part of the unit, any participating centre has resources for its safe working practices.

Useful Websites

Listed below are websites that may be of assistance to you or your students:

- **Careers, Safety and Employability**

  Careers Scotland
  http://www.careers-scotland.org.uk/home/home.asp

  SEMTA
  http://www.semta.org.uk/

  The Scottish Electrical Charitable Training Trust
  http://www.sectt.org.uk/

  EMTA Awards Ltd (EAL) Engineering and Technology industry awarding body
  http://www.eal.org.uk/

  Health and Safety Executive
  http://www.hse.gov.uk

  COSHH – Control of Substances Hazardous to Health
  http://www.hse.gov.uk/coshh/

  Employability Framework for Scotland
  http://www.scotland.gov.uk/Topics/Business-Industry/Employability

- **Electrical and Electronic**

Simple Electrical Circuits
http://www.zephyrus.co.uk/circuits1.html

Electrical Circuits by Kevin R Sullivan
http://www.autoshop101.com/trainmodules/elec_circuits/circ101.html

FCs Electronic Circuits
http://www.solorb.com/elect/

Lessons in Electric Circuits by Tony R Kuphhaldt
http://www.ibiblio.org/obp/electricCircuits/

NGFL Wales: Electric Circuits
http://www.ngfl-cymru.org.uk/vtc/learnpremium/electric_circuits/Introduction/default.htm

Department for Education and Skills: Standards Sites: Electrical Circuits
http://www.standards.dfes.gov.uk/schemes2/secondary_science/sci07j/?view=get

Electricity: Simple Circuits by Janice Simpson
http://www.can-do.com/uci/lessons99/electricity.html

Circuit-Magic: Circuit Analysis Tutorial
http://www.circuit-magic.com/laws.htm

Technology Student by V Ryan
http://www.technologystudent.com/

Wikipedia: free encyclopedia
http://en.wikipedia.org/wiki/Main_Page

The Scots Guide to Electronics
http://www.st-andrews.ac.uk/~jcgl/Scots_Guide/intro/electron.htm

Everyday Practical Electronics(EPE) magazine
http://www.epemag.wimborne.co.uk/

Electronic Tutorials by Ian Purdie (Australia)
http://www.electronics-tutorials.com/

The Blobz Guide to Electric Circuits by Andy Thelwell
http://www.andythelwell.com/blobz/

Lessons, Materials and Tools

In the following lesson plans, which are intended as a guide only, the simple practical tasks are designed to develop basic electrical and electronic engineering skills such as:

- Identification, selection and use of tools and equipment
- Identification, selection and use of cables and accessories
- Identification, selection and use of cables and components
- Interpretation of engineering drawings and specifications
- Electrical circuit construction
- Electronic circuit construction
- Employability skills

Each lesson should start with the health and safety requirements that will be applicable to that particular lesson and any additional PPE that might be required.

In each Lesson Plan, the tools and materials applicable to the lesson are listed. This list is for guidance only and can be supplemented as necessary.

It is hoped that in the use of tools and materials, or if specific problems arise, this will lead to discussion about roles and responsibilities in industry. This could include manufacturing processes or indeed any processes used in local firms.

Practical Tips

It is expected that as each basic practical skill is demonstrated, good practice will be emphasised and that any good trade specific hints or tips should be included in the lesson. It is also advised that the following should be integrated with the range of practical activities:

- The use of employed apprentices attending college to aid workshop sessions
- The use of various speakers/experts/tradespersons to aid employability skills and knowledge of local industry
- The use of ICT if appropriate

Lesson 1

Interpret and Use Manufacturers' Drawings and Specifications

Objectives:

- Use safe working practices, health and safety regulations and employability.
- Identify and use tools by name and purpose – the safe use and recognition of tools in terms of their name and purpose. Emphasis should be on the correct use for each tool.
- Use correct methods of handling, care of and storage of tools – the correct method of tool transportation, the care of the tool in terms of usage and storage should be demonstrated and emphasised.

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Tools:

• Snips	• Pliers (various)	• Wire strippers
• Crimping tool	• Screwdrivers (various)	• Files (various)
• Solder irons	• Circuit assembly aids	• Junior hacksaw
• Solder stand	• Crimping pliers	• Footprints
• Rule	• Adjustable wrench	• Tape measure
• Hammer	• Chisel	• Hacksaw

Learning and teaching process:

- use group discussion to determine the level of student knowledge of health and safety issues with respect to electrical safety; develop this to discuss the need for general health and safety in the workshop environment; emphasise the student's own health and safety and that of others in the workplace
- use small groups to establish the requirements for a safe learning environment, what that environment will look like, feel like and sound like. Small class groups of no more than 5 can design a poster that will list all the requirements necessary for a safe learning environment. Groups should be given around 15 minutes to complete their poster. Completed posters can be displayed around the workshop, if appropriate. Use the results to promote awareness of a safe learning environment for individual and class groups. This can then be extended to the general learning environment and the development of employability skills such as attendance, punctuality, working with others etc.
- identify listed tools by name
- identify listed tools by purpose
- state and demonstrate the correct methods/techniques of using listed tools
- allow students to practise tool usage on simple tasks
- use group discussion to develop the need for proper care and storage of listed tools

Tool Identification

Your tutor will show you a selection of numbered tools – fill in the table with what you think they are called and what they do.

Tool	**Tool Name**	**Tool Purpose**
Tool 1		
Tool 2		
Tool 3		
Tool 4		
Tool 5		
Tool 6		
Tool 7		
Tool 8		

Lesson 2

Cut and Terminate Cable

Objectives:

- use safe working practices, observe health and safety regulations and remember employability skills
- identify cable types
- use the correct measurement units
- identify cable terminations
- use the correct marking, cutting and termination tools
- use these tools solely for their intended purpose
- check the cable against the work instructions
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Tools for cutting, stripping and terminating:
    - Rule
    - Tape measure
    - Snips
    - Wire strippers
    - Crimpers
- Electrical cable and ring tabs

Learning and teaching process:

- discussion of health and safety issues
- interpretation of work instructions
- identification of common cable types
- demonstrate correct cutting, stripping and terminating
- allow students to practise cutting, stripping and terminating
- student quality check
- use group discussion to highlight difficulties encountered

Cut and terminate cable – Work instructions

1. Cut 4 pieces of multi-strand cable 250mm long
2. From each end - strip the insulation for about 6 - 8mm
3. Fit the crimp terminal over the exposed copper conductor
4. Use the crimping tool to compress the crimp onto the copper conductor

Lesson 3

Cut and Terminate Cable to Accessories

Objectives:

- use safe working practices, observe health and safety regulations and remember employability skills
- identify cable types
- use the correct measurement units
- identify cable terminations/accessories and symbols
- use the correct marking, cutting and termination tools
- use these tools solely for their intended purpose
- check the cable against the work instructions
- connect accessories correctly
- connect accessories without damage
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Tools for cutting, stripping and terminating:
    - Rule
    - Tape Measure
    - Snips
    - Wire Strippers
    - Screwdrivers
    - Pliers
- Electrical cable, earth sleeving and accessories

Learning and teaching process:

- discussion of health and safety issues
- interpretation of work instructions
- identification of common cable types
- identification of common accessories and symbols
- demonstrate correct cutting and stripping of cables
- allow students to practise cutting and stripping of cables
- demonstrate correct termination of cables to accessories
- allow students to practise termination of cable to accessories
- student quality check - termination of accessories
- student quality check - integrity of accessories
- use group discussion to highlight any difficulties encountered.

Cut and Terminate Cable to Accessories – Work instructions

1. Cut 3 pieces of twin and earth (T & E) cable 500mm long
2. At one end of the T & E strip the outer insulation for about 40mm, then strip the inner insulation for about 6 - 8mm
3. Connect the first T & E cable to the lamp holder
4. Connect the second T & E to the one way switch
5. Connect the third T & E to a Consumer Unit
6. Mount the accessories on a suitable board.

Lesson 4

Construct and test a one way switched lighting circuit

Objectives:

- use safe working practices, observe health and safety regulations and remember employability skills
- identify cable types
- use the correct measurement units
- identify cable terminations/accessories and symbols
- use the correct marking, cutting and termination tools
- use these tools solely for their intended purpose
- check the cable against the work instructions
- check the cable route against the work instructions
- fit the accessories correctly
- connect accessories correctly and without damage
- continuity test the circuit conductors
- function test the circuit
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Tools for cutting, stripping and terminating:
    - Rule
    - Tape measure
    - Snips
    - Wire strippers
    - Screwdrivers
    - Pliers
- Electrical cable, earth sleeving and accessories
- Circuit board
- Continuity tester

Learning and teaching process:

- discussion of health and safety issues
- interpretation of work instructions
- identification of common cable types
- identification of common accessories and symbols
- demonstrate correct cutting and stripping of cables
- allow students to practise cutting and stripping of cables
- demonstrate correct routing of cables
- allow students to practise correct routing of cables
- demonstrate correct fitting of accessories
- allow students to practise correct fitting of accessories
- demonstrate correct termination of cables to accessories
- allow students to practise termination of cable to accessories
- demonstrate continuity tests on circuit conductors
- allow students to practise continuity tests on circuit conductors
- demonstrate function tests on circuit conductors
- allow students to practise function tests on circuit conductors
- use group discussion to highlight difficulties encountered
- student quality check - termination of accessories
- student quality check - integrity of accessories
- student quality check – circuit continuity and functionality
- student quality check - integrity of accessories
- use group discussion to highlight difficulties encountered.

NB Each circuit will require more than just a continuity test before connection to whatever circuit supply is being used.

Construct and test a one way switched lighting circuit – Work instructions

1. Measure and mark the board as shown in the board layout diagram.
2. Fit the accessory bases on a suitable board.
3. Run the T & E cable to/from each accessory.
4. Connect the T & E to the one way switch.
5. Connect the two T & E cables at/to the lamp holder.
6. Complete continuity tests.
7. Complete functionality test.

Lesson 5

Electronic Component Identification

Objectives:

- Use safe working practices, observe health and safety regulations and remember employability skills.
- Identify electronic components.
- Identify electronic component circuit symbols.
- Use correct methods of handling and connecting certain electronic components.

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Electronic components

Learning and teaching process:

- discussion of health and safety issues
- identification of circuit components
- handling and care of circuit components
- composition and materials of circuit components
- student quality check
- use group discussion to highlight difficulties encountered.

Electronic Component Identification

Your tutor will show you a selection of numbered electronic components – fill in the table with what you think they are called, their circuit symbol and if appropriate the component value.

Component	Component Name	Component Symbol	Component Value
Component 1			
Component 2			
Component 3			
Component 4			
Component 5			
Component 6			
Component 7			
Component 8			

Remember Employability

Do you have a positive attitude to learning?
Ask questions – if you are not sure of something

Lesson 6

Soldering – Wire Termination

Objectives:

- use safe working practices, observe health and safety regulations and remember employability skills
- use the correct measurement units
- use the correct marking, cutting and termination tools
- use the tools solely for the intended purpose
- check the cable against the work instructions
- tin the cable and trim to size
- solder the cable to an electronic construction board
- desolder the cable from the electronic construction board
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Tools for cutting, stripping and soldering:
  - Rule
  - Tape measure
  - Snips
  - Wire strippers
  - Solder iron
  - Solder sucker
  - Solder
  - Solder stand
- Electrical/electronic cable (various) and an electronic construction board.

Learning and teaching process:

- discussion of general health and safety issues
- specific health and safety issues about soldering and fumes
- interpretation of work instructions
- demonstrate correct cutting, stripping, soldering and desoldering
- student quality check
- quality check – solder joints and cable insulation heat damage
- use group discussion to highlight difficulties encountered.

Soldering – Wire Termination – Work Instructions

1. Cut the various cables to length (200mm)
2. Strip the insulation (10mm)
3. Tin the copper conductor
4. Trim the length of tinned end to 4mm – 6mm
5. Solder the cable to the board, trim if required.

Lesson 7

Soldering Solder – Desolder – Termination of Components

Objectives:

- use safe working practices, observe health and safety regulations and remember employability skills
- use the correct cutting, bending and soldering tools
- use the tools solely for the intended purpose
- check the components against the work instructions
- bend components to the correct shape and secure to the board
- solder components to the electronic construction board
- components soldered without damage
- desolder components from the electronic construction board
- components desoldered without damage
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Tools for cutting, bending and soldering:
  - Solder
  - Helping hands
  - Component bender
  - Pliers
  - Solder iron
  - Solder stand
  - Snips
  - Solder sucker
- Electronic components (various) and an electronic construction board

Learning and teaching process:

- discussion of general health and safety issues
- specific health and safety issues about soldering and fumes
- interpretation of work instructions
- demonstrate correct component bending and soldering
- allow students to practise component bending and soldering
- student quality check
- quality check – solder joints and component integrity
- demonstrate correct component desoldering
- allow students to practise component desoldering
- student quality check
- quality check – component integrity
- use group discussion to highlight difficulties encountered.

Soldering Solder – Desolder – Termination of Components Work Instructions:

Solder

1. Bend components to shape
2. Secure to board
3. Secure components to the board
4. Desolder components from the board.

Lesson 8

Construct and test a simple car parking light

Objectives:

- use safe working practices, observe health and safety regulations and remember employability skills
- use the correct cutting, bending and soldering tools
- use the tools solely for the intended purpose
- check the components against the work instructions
- bend components to the correct shape and secure to the board
- solder components to the electronic construction board
- components soldered without damage
- complete continuity test on circuit wire links
- function test circuit
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity

Resources:

- PPE
- Student Support materials
- Work instructions (see below)
- Tools for cutting, bending and soldering:
  - Solder
  - Helping hands
  - Component bender
  - Pliers
  - Solder iron
  - Solder stand
  - Snips
  - Solder sucker

Electronic components (various) and an electronic construction board

Learning and teaching process:

- discussion of general health and safety issues
- specific health and safety issues about soldering and fumes
- interpretation of work instructions
- demonstrate correct component bending and soldering
- allow students to practise component bending and soldering
- student quality check
- quality check – solder joints and component integrity
- demonstrate continuity tests
- function test circuit
- student quality check
- quality check – component integrity
- use group discussion to highlight difficulties encountered.

Construct and test a simple car parking light – Work Instructions

1. List components required
2. Check components against board size
3. Bend components to size
4. Secure components to board
5. Solder components to board
6. Complete circuit continuity tests
7. Complete circuit function test

Extension Activities

Additional activities which can be used with students who have completed all the Lesson Assignments in this pack ahead of schedule are found at the end of the Student Support Section.

Practical Activity Checklist

Candidate Name	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Activity 8

Student Support Section

Tutor Note on Student Activities

This section includes both student notes and activities. Use of these materials is not mandatory and they are offered to centres as a flexible set of materials and activities which can be selected, altered and used to supplement tutors' own tried and tested materials, or in whatever way suits individual centres and their particular situation. For example, in the case of the student activities you might want to talk through the instructions with the learners and then give the instructions out on paper as reminders. The notes are not intended in any way to replace the tutor!

They should not be issued as a pack of student notes in their entirety. Rather they are designed to be issued in small sections only, to reinforce practical workshop activity. In the case of the student activities you might want to talk through the instructions with the learners and then give the instructions out on paper as reminders.

Because of the technical nature of the subject and the terminology, handout materials on electrical/electronic theory should only be issued after the topic has been fully covered with the students.

Extension Activities

There is a significant degree of similarity between the Intermediate 1 Engineering Skills: Electrical/Electronic Unit and the Intermediate 2 Engineering Skills: Electrical and Electronic Unit.

This means that the activities of this Intermediate 2 Engineering Skills: Electrical and Electronic support pack are similar to the activities of the Intermediate 1 Engineering Skills: Electrical/Electronic support pack. This is necessary however, for use with students who have not progressed through the Intermediate 1 route.

Students who have previously completed the practical activities of the Intermediate 1 Engineering Skills: Electrical/Electronic support pack and are now attempting the practical activities of the Intermediate 2 Engineering Skills: Electrical and Electronic support pack will therefore require additional activities.

These additional activities are found at the end of this Student Support Section.

Welcome to the Electrical and Electronic Unit

In the Electrical and Electronic Unit you'll select the correct tools and components needed to construct a basic functional extra low voltage electrical circuit and an electronic circuit from a given diagram and specification.

If you have previously completed the *Engineering Skills: Electrical/Electronic Unit at Intermediate 1* you will find that you will develop additional practical and employability skills in this Unit.

The Unit is designed to be practical and this means that you'll be in a workshop for all the activities. Local industries and workshop facilities might be the deciding factor on the type of electrical and electronic circuit construction you do.

At the same time you'll be developing Employability Skills - these are the skills that employers value. A small number of these skills will apply only to engineering but most of the Employability Skills are transferable and will be applicable in whatever career you choose to follow.

All Employability Skills are important but it could be argued that the most important one is understanding about Health and Safety. Health and Safety will be emphasised through each practical activity of the course and is there to protect you and all the other people in the workshop.

The Electrical and Electronic Unit is split into four outcomes which state what you should be able to do by the end of the Unit:

- Identify, select and use a range of tools to terminate and test electrical cables and accessories.
- Identify, select and use a range of tools to terminate and test electronic cables and components.
- Construct and test circuits from given diagrams.
- Review and evaluate own employability skills in practical engineering contexts.

Electrical Safety

Electricity can and does kill!

Electricity is like the 'Fantastic Four':

- It will stretch across exposed cables and faulty equipment to shock you.
- It is invisible, so you cannot see it coming to get you.
- It causes fire through faulty wiring and equipment.
- It is a brute force if you receive a shock.

Accidents

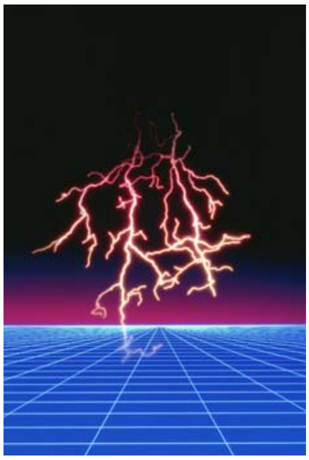
There are about 1000 **accidents** reported to the Health and Safety Executive every year concerning electric shock or burns. These reported accidents occurring in the workplace cause around 30 deaths every year.

However the dangers from electricity are not just to those who work in the electrical industry. Many **domestic accidents** happen because of poor electrical installations or faulty electrical appliances both of which can lead to fires or injuries to persons.

Portable electrical equipment accounts for nearly 25% of all accidents annually, so every precaution must be taken when using portable tools.

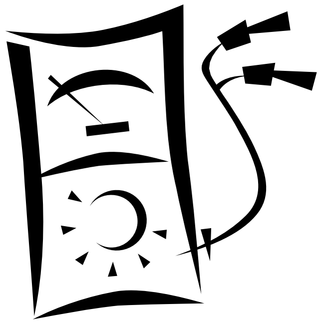
Most accidents can be avoided by:

- a well thought out plan of action for each job
- common sense precautions.
- elimination of unnecessary risks



Remember everyone is responsible for the safety of themselves and others.

This unit is designed to give you an introduction to electrical and electronic circuits. Successful completion of this unit means that you will be able to:



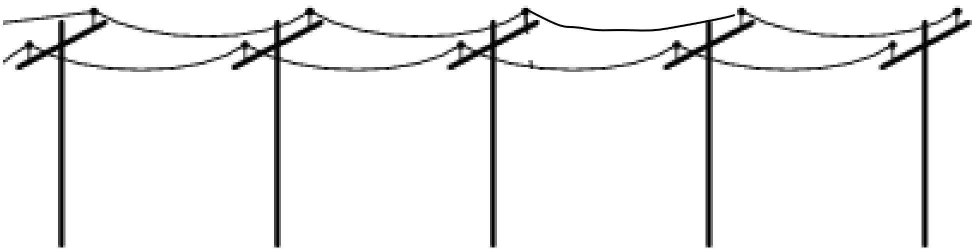
- recognise commonly used cables
- recognise electrical accessories
- recognise electronic components
- use simple continuity tests.

This is a first step but remember:

It takes at least **4 years of training** as an apprentice, to become **competent** as an **Electrical Engineer.**

Dangers of Electricity

Humans are not really built to sustain or experience an electric shock. Our bodies are engineering miracles that can perform skills in some unbelievable ways - like gymnasts or footballers - but our bodies are not capable of carrying an electric current without severe damage or death.



Hopefully most of us will never experience some form of electric shock. An electric shock causes our body to experience pain, trauma or both. An electric shock can be measured on a scale for humans from a slight tingle right up to unbearable pain. The effect of an electric shock can be slight paralysis right up major paralysis of the body's vital organs. In addition to this there can be serious burns from the electric current.

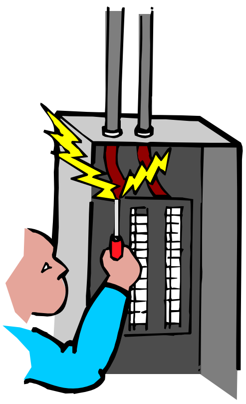
Electric Shock

A person will receive an electric shock if they touch a 'live' conductor or part of a circuit that is 'live'. The person receiving the electric shock provides another, easier path, for the electricity to flow.

Electricity is a power we should harness and enjoy but also we should be aware of the dangers and danger signs.

Dangers:

Shock



Fire

It is very important that the dangers of electricity are minimised or completely eliminated when working with circuits.

Prevention of Electric Shock

The easiest way to ensure safety is for all circuits to be disconnected from the supply (the term for this is isolated) before working on them, but this is not always possible.

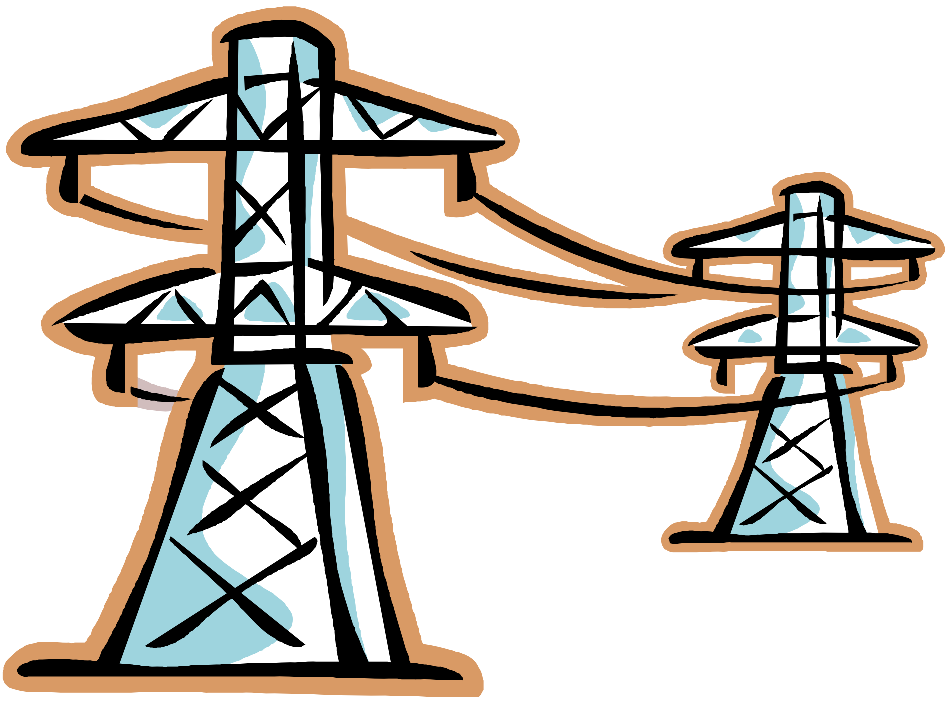
Normally each part of an electrical circuit is **insulated** from human contact and all equipment is **earthed**.

Insulated

This means that most of the equipment is encased in plastic and does not have any exposed metal parts that can be touched.

Earthing

This involves connecting together all exposed metal parts to a common **earth conductor** which is designed to provide an easy path for the electric current to flow. This easier path allows a large current to flow which then causes the **fuse**, Miniature Circuit Breaker (**MCB**) or Residual Current Device (**RCD**) to operate and break the circuit. The terms MCB and RCD are explained later. The earth conductor is also called the Circuit Protective Conductor or **CPC** for short.



Fire

Every electric current that flows through a circuit generates heat in the cables and in the joints of the cable conductors.

Normally this generated heat is taken into account when the circuit is designed (cable size, accessory rating etc) so that this is not a problem but, if the cable used is 'too small' or if a joint is not made correctly (ie. the cable terminations are not tight), then overheating could result and this could start a fire.

Fire Prevention

Electricity regulations deal with the problem of overheating cables and the prevention of fires which might result from this.

To prevent a cable overheating:

- calculate the circuit load current
- select a cable large enough to carry that current

Note:

The electrical regulations provide standard tables and give guidance to help select the correct cable size for a particular load current.

Good workmanship and the use of proper materials is another feature of the electricity regulations.

It is important that electricians use the correct materials for the job and that their workmanship always meets the high standards expected.

If this is the case then they will make sure that all their work, including joints and terminations, are properly made so that there is no danger of shocks and fires.

Activity

2, 5

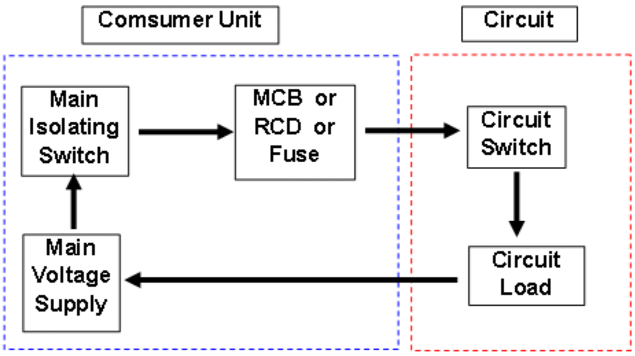
Safety Poster

In groups of 4, taking no more than 20 minutes, design a safety poster that highlights some of the dangers of electricity.

Isolating

The safest way to work on any electrical or electronic circuit is for that circuit to have all power removed from it, which means that it is disconnected from the main **voltage** supply. This is called isolated.

Wires that are connected to a voltage supply look exactly the same as wires that are disconnected from the supply. It would be nice if wires that are connected to the voltage supply gave us an audible or visual warning but this is not the case, therefore safety measures to isolate the circuit must be taken.

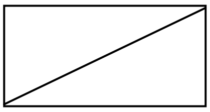


The main voltage supply in any house comes into the house at the **consumer unit**. So it makes sense that the main isolation switch for all the circuits in the house is also in the consumer unit. The **consumer unit** is where each circuit starts and finishes so each circuit protection device whether it's a Residual Current Device (RCD), Miniature Circuit Breaker (MCB) or fuse is also in the consumer unit.

The safest way to work on a circuit is to isolate the circuits at the consumer unit by switching off the Main Isolating Switch, in order to isolate all circuits in the house.

With the Main Isolating Switch in the 'open' position, all the circuits are broken and no current will exist.

Circuit Symbol



Signs of Danger

Should we be scared of electricity? – **YES** we should.

Danger Signs:

- sockets and plugs that are hot
- circuits that trip for no obvious reason
- lights that flicker
- sockets or plugs with scorch or burn marks
- plugs with frayed or repaired wiring
- overloaded sockets
- cables in vulnerable positions (cables over/under mats, carpets or laminate flooring)
- water near electrics (water and electricity do not mix)
- incorrect fuse rating

Remember!

- plugs should be wired carefully and by a competent person
- throw away damaged cables
- turn off and unplug electrical appliances when not in use.

Activity: Signs of Danger

2

In the table below list 4 common signs of danger for electrical circuits:

Number	Sign of Danger
1	
2	
3	
4	

Suggested Answers

Signs of Danger

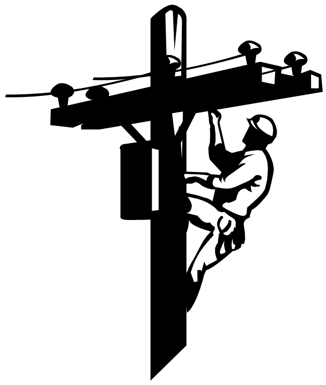
Any 4 from the following:

Number	Sign of Danger
1	sockets and plugs that become hot
2	circuits that trip for no obvious reason
3	lights that flicker
4	sockets or plugs with scorch or burn marks
5	plugs with frayed or repaired wiring
6	overloaded sockets
7	cables in exposed positions
8	damaged cables
9	incorrect fuse rating
10	plugs incorrectly wired
11	water near electrics

Turn off and unplug electrical appliances when not in use.

Rules and Regulations of Electrical Wiring

Society is so used to utilising the power of electricity that it has become a part of modern life. Computers, game consoles, phone chargers, TVs, fridges, irons, kettles, toasters, food processors, clocks, lights, and alarm systems. You name it, we use it, and a great deal is powered by an electric supply or current of 230 volts which will kill us if we touch an exposed or bare conductor.



The problem with electrical wiring and appliances is that there are many dangers involved. The dangers of fire and electrical shock are very real and lives are lost each year because of faults in electrical circuits and appliances. It stands to reason that there must be some rules and regulations to govern the installation of electrical circuits.

The standard for electrical wiring are the **IEE Wiring Regulations**, often referred to as 'the regs'. These deal with the safety of electrical wiring in buildings whether domestic, commercial, farms, industrial or any other. These are regulations, not rules, and as such are only recommended practice. However, it is a different case in England and Wales.

Electricity at Work Regulations 1989

These regulations came into effect in April 1990, under the umbrella of the Health and Safety at Work Act 1974 which clearly outlines the responsibilities of employers and employees. The Act covers electrical installations, safe and suitable equipment, maintenance, safety devices for circuits and the competence of persons completing electrical work.

The *Electricity at Work Regulations 1989*, however are **rules** and clearly state who will be held responsible in the eyes of the law if all the regulations are not adhered to.

Current – Voltage – Resistance

The relationship between current, voltage and **resistance** is important to all electrical engineers.

	Current	**Voltage**	**Resistance**
Symbol	I	V	R
Unit	Ampere (A)	Volt (V)	Ohm (Ω)

What exactly are voltage, current and resistance?

This is a picture of the Hoover Dam.

Current (symbol **I**) is like the water flowing from the overflow valve in the side of the dam.

Voltage (V) can be likened to the pressure of water. The more water in the dam - the more pressure pushing water out. It's the same with voltage: more voltage = more current.

Resistance (R) in this case is the size of the opening of the overflow valve. If the valve is slightly open then the flow pressure would be high and if the valve is fully open the flow pressure would be lower.

Apply this to an electrical circuit:

Current (I) is what **flows through a wire or conductor** like water flowing out of the dam. Current flows from points of high voltage to points of low voltage through the conductor. Current is measured in **amperes** (A). Ampere is shortened to amp.

Voltage (V) or sometimes (E) is the difference in electrical potential between two points in a circuit. It's the push or **pressure behind the current flow** through a circuit, and is measured in **volts (V)**.

Resistance (R) determines how much current will flow through a component. **Resistor**s are **used to control voltage and current levels**. A very high resistance allows a **small amount of current** to flow. A very **low resistance** allows a **large amount of current** to flow. Resistance is measured in **ohms (Ω)**. The relationship between V, I and R is stated in **Ohm's Law**.

Ohm's Law

Ohm's law states that, in an electrical circuit the current (I) that flows is **directly proportional** to the voltage applied to the circuit.

What this really means is that:

If the voltage increases $\rightarrow$ **the current increases**
and
If the voltage decreases $\rightarrow$ **the current decreases**

Georg Ohm

Also if the voltage remains constant (this is what happens in most circuits) then the resistance and current are **indirectly proportional**.

What this means is that:

If the resistance decreases $\rightarrow$ **the current increases**
and
If the resistance increases $\rightarrow$ **the current decreases**

Weird or What,?? Anyway, try this with some simple figures:

If the voltage source remains constant at 100V look what happens to the current as the resistance increases:

Voltage (V)	**Resistance (Ω)**	**Current (I)**
200V	1 Ω	200A
200V	10 Ω	20A
200V	100 Ω	2A
200V	1000 Ω (1k Ω)	0.2A (200mA)

The relationship between voltage, current, and resistance is given by a simple equation derived from Ohm's Law. Fill in the blanks:

$V = IR$ Voltage = Current x Resistance

This will mean that: $I = \frac{V}{R}$ Current = __________ ÷ ____________

and $R = \frac{V}{I}$ ______ = __________ ÷ ____________

Circuits

In any circuit, if there is a source of energy and a load, a current will flow. The current flows through the components and this in turn creates a voltage drop across each component.

Power

Symbol **P** Unit **Watt (W)**

The power used or dissipated in a circuit can be calculated from the:

Current - Voltage - Resistance

If any two of the above are known then the power can be calculated from:

$P = VI$ Watt or $P = I^2R$ Watt or $P = \frac{V^2}{R}$ Watt

Voltage V	**Current I**	**Resistance R**	**Power P**
100V	10A		1000W
12V		2Ω	72W
	15A	4 Ω	900W

Activity: Electrical Symbols and Units

Complete the following table of electrical symbols and units:

	Current	Voltage	Resistance
Symbol			
Unit			

Calculations – Ohm's Law and Power

Complete the table:

Voltage V	Current I	Resistance R	Power P
100V	5A		
12V		1Ω	
	5A	8Ω	
230V	13A		
	3A	150Ω	
50V		20Ω	
		40Ω	1kW
	0.5A		2.5W
250V			62.5W

Remember k means 1000

Remember to write the units.

Answers

Electrical Symbols and Units

Complete the following table of electrical symbols and units:

	Current	**Voltage**	**Resistance**
Symbol	I	V	R
Unit	Ampere (A)	Volt (V)	Ohm(Ω)

Calculations – Ohm's Law and Power

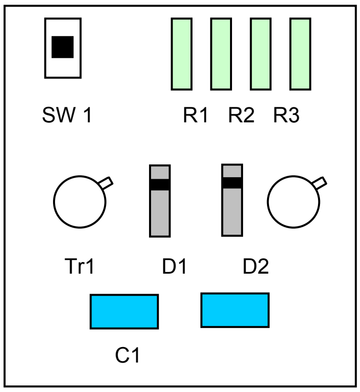
Voltage V	**Current I**	**Resistance R**	**Power P**
100V	**5A**	20Ω	**500W**
12V	**12A**	1Ω	**144W**
40V	5A	8Ω	**200W**
230V	13A	**17.7Ω**	**2990W**
450V	3A	150Ω	**1350W**
50V	**2.5A**	20Ω	**125W**
200V	**5A**	40Ω	1kW
5V	0.5A	10Ω	2.5W
250V	**0.25A**	**1kΩ**	62.5W

Did you remember to write the units?

Diagrams

In electrical and electronic circuitry there are different types of diagrams:

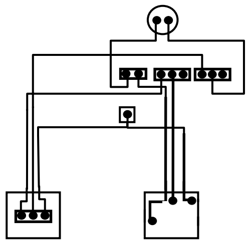
Layout Diagram



Component Position

Layout diagrams show the physical position of each component or circuit accessory. This type of diagram shows only the location of a switch or relay or resistor and does not show any interconnections or wiring details. This type of diagram is widely used in the installation of new circuits but is also extensively used in the maintenance and repair of circuits.

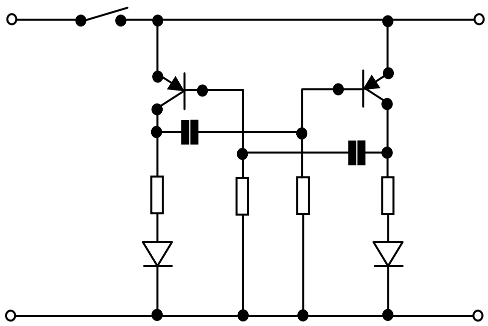
Wiring Diagram



Cabling and Connections

Wiring diagrams show the route the cabling or wiring actually takes and would possibly give the connection details as well. The wiring and layout diagrams are the most widely used for the installation of circuits whether it is for an aircraft, a motor car or a new house.

Circuit Diagrams



How the Circuit Operates

Circuit diagrams show all the components and interconnecting wiring without any details of cable routes or the component positions. This is the most widely used diagram for fault finding and repair of circuits. This diagram shows how the circuit operates without showing the physical layout.

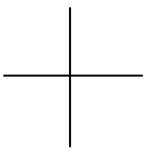
Block Diagram

Circuits in Block Form

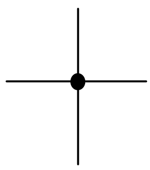
A **block diagram** is a simple diagram in which a circuit or system is split into simple blocks that are labelled with the function of the block.

Wires Crossing/Connection Convention

Wires Crossing



Wires Connected



Circuit Protection

There are two main methods of protection for electrical circuits:

- Fuse or Miniature Circuit Breaker (MCB)
- Earthing and Residual Current Device (RCD)

In general:

- fuses and MCBs protect the appliance, and
- earthing and RCDs protect people.

Fuses

Fuses are used to protect the appliance. If the circuit current goes high because of a fault the fuse should blow and break the circuit. This is called an '**open circuit**', but this method of safety only works if the right rating of fuse is fitted. The simplest fuse has a single wire connected between the fuse terminals and if the current is too large the wire simply melts and breaks.

A very rough guide is 250 watts to 1 ampere (amp).

In general the following applies:

- Appliances that use up to 700 watts: 3 amp fuse
- Appliances that use 700 to 1000 watts: 5 amp fuse
- Appliance that use 1000+ watts: 13 amp fuse

If in any doubt check the appliance's handbook.

Miniature Circuit Breaker (MCB)

The MCB is also designed to protect the appliance and will 'open circuit' in the event of a larger than normal current flow that has resulted from a fault. The fuse or MCB is designed to protect the appliance and is not really designed to protect people.

The MCB is like a fusible switch so that if a large current flows, the switch clicks to the **OFF** position.

The advantage of the MCB is that it is easily reset to the **ON** position.

MCBs are used in many circuits:

heating circuits - **lighting circuit**s - power circuits

Residual Current Device (RCD)

The Residual Current Device works rather like the MCB but an RCD is more likely to be used in **power circuits**.

The RCD constantly compares:

- the current in the live conductor with the current in the neutral conductor.

If there is a slight imbalance between the two currents, the RCD trips, and 'open circuits' the circuit. The slight imbalance in circuit current balance may represent current leakage through the body of a person who is:

- touching a live wire
- accidentally touching the live part of the circuit.

In other circumstances these electric shocks could prove to be fatal but with an RCD in the circuit, the circuit will quickly be broken.

RCDs have saved countless lives and are, in many peoples' opinion, one of the best safety devices ever invented, if not the best.

Picture of RCD sourced from Wikipedia.org

Earthing

Earthing involves connecting together all exposed metal parts to a common **earth conductor** which is designed to provide an easy path for the electric current to flow.

This easy path lets a larger than normal current flow which should then cause the:

> ***Fuse*** to operate and 'open circuit' the circuit.
>
> *or*
>
> ***Miniature Circuit Breaker*** *(MCB)* to operate and 'open circuit' the circuit.
>
> *or*
>
> ***Residual Current Device*** (*RCD*) to operate and 'open circuit' the circuit.

The **earthing** of metal parts is designed to protect people and is not designed to protect electrical appliances. It also holds all touchable metal in a house to the same voltage (about zero volt) to **prevent electrical shocks** when touching two metal objects at the same time. The earthing cable is also known as the **Circuit Protective Conductor (CPC)**.

Connecting all the exposed metal parts is called **bonding**. If there was no earth bonding and a live wire was touching the copper pipe going to the kitchen sink, anyone who touched the sink would receive an electric shock. This cannot happen with properly connected earth bonding.

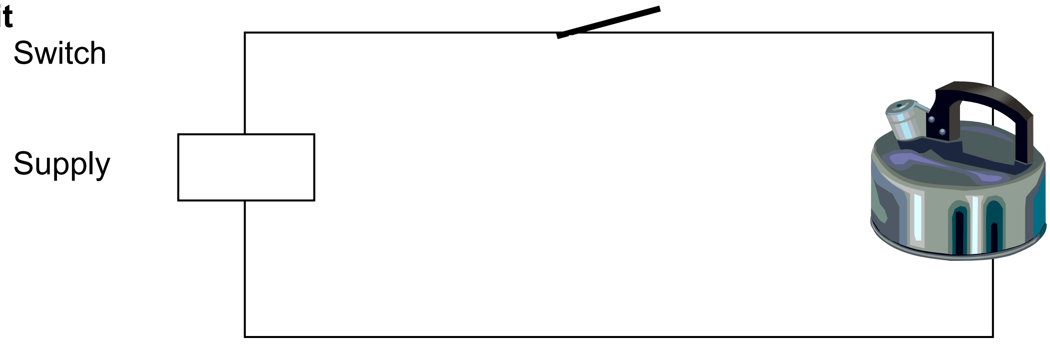
The **Electricity Regulations** set out safety rules to prevent and reduce the risk of electric shock to people.

Whilst the risk of shock cannot be completely prevented (a person may deliberately take risks or ignore the rules), it can be greatly reduced if the rules are followed.

Shocking Thought!

The smallest fuse in a house wiring system is 5 ampere (5A). People start to feel an electric shock (depending on circumstances) at around about 0.001 ampere and for some people 0.1 ampere could be fatal.

Open Circuit



An **open circuit** is a break anywhere in a circuit and could be caused by a:

Switch	Fuse	MCB	RCD

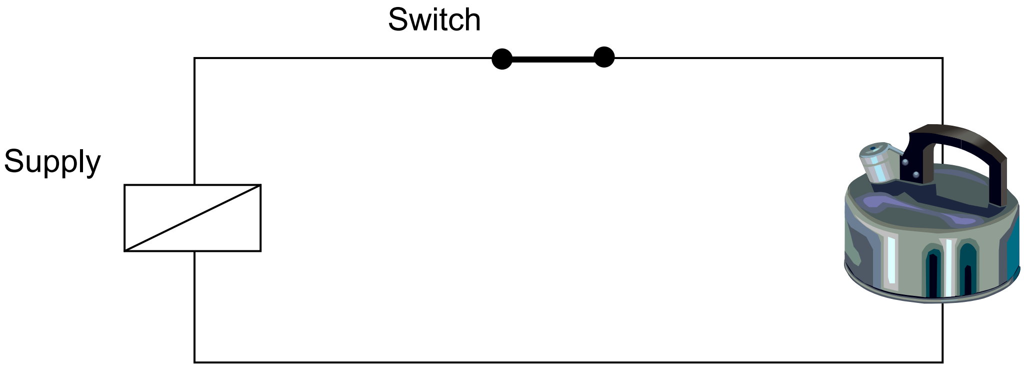
or a

Faulty cable	Faulty connection	Faulty accessory

Please Note:

In this case the circuit is very dangerous because some parts of the circuit may still be 'LIVE' and must not be worked on until the complete circuit has been isolated.

Complete Circuit

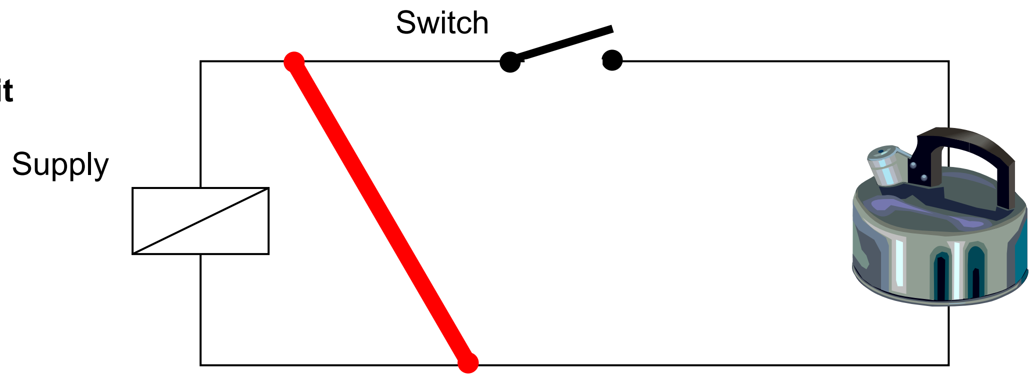


A **complete circuit** means that the circuit is continuous and has no breaks.

Short Circuit

A short circuit is when there is an unplanned connection between the 'live' and 'neutral' conductors usually under fault conditions.

Short Circuit



In short circuit conditions a very high current will flow. The current is high because the resistance path of the short circuit is very low. The protective devices are designed for this eventuality and should operate to break the circuit.

If this high current were allowed to flow for any length of time it would cause great heat and this could cause a fire, but the fuse or MCB will operate almost instantly to break the circuit (remember this is called an open circuit).

Short Circuit → Very High Current

Very High Current → Fuse or MCB - breaks circuit

Short Circuit → Open Circuit

Please note that under certain short circuit conditions the RCD would not operate.

The RCD compares the current in the live conductor against the current flowing in the neutral conductor and will only operate if there is a small difference.

Activity

1. In the following state whether the appliance or the person is being protected:

A MCB is designed to protect:	Appliance Person
Earthing is designed to protect:	Appliance Person

2. In circuit safety devices what do the following abbreviations stand for:

RCD ____

MCB ____

3. What is the electrical cable connected to the water pipe called?

____

4. What on earth does this cable do and is it necessary?

____

____

____

Answers to Activity

1. In the following state whether the appliance or the person is being protected:

A MCB is designed to protect: **Appliance**

Earthing is designed to protect: **Person**

2. In circuit safety devices what do the following abbreviations stand for:

RCD **Residual Current Device**

MCB **Miniature Circuit Breaker**

3. What is the electrical cable connected to the water pipe called?

Earth or CPC

4. What on earth does this cable do? Is it necessary?

- It connects all the exposed metal parts together at roughly the same voltage potential as the earth in your garden.
- If a live wire then touches any exposed metal part there is an easy path for the electricity to flow.
- This easy path has a very low resistance and lets a very high current flow and this will cause the fuse to break or the MCB to trip and break the circuit.

Materials

All of the practical activities in this electrical/electronic unit involve the use of a range of tools and equipment made of different materials. The range of materials includes:

- ferrous
- non-ferrous
- non-metallic

Ferrous

Ferrous metals contain iron (this material will rust) and are used for metal:

- switch boxes
- **consumer unit**s
- conduit.

Non-ferrous

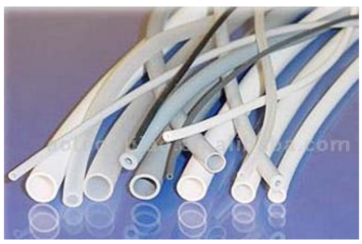
Non-ferrous materials do not contain iron - (therefore they will not rust or corrode). Copper is **non ferrous** and is widely used in the wiring of electrical/electronic applications.

Non-metallic

Non metallic materials contain no metals (generally these are resistant to corrosion). This term applies to plastic.

There are two basic types of plastic:

Thermosetting plastics used for electrical sockets etc.



Thermoplastic plastics are used for mini-trunking, conduit tubing and electrical cable insulation.

Properties

Electrical Conductivity

Conductivity is the ability of a material to let a current flow.

Silver, gold and copper have good conductivity but silver and gold are too expensive to be used for electrical wiring so copper is widely used.

Electrical Insulation

Insulation is the opposite of conductivity and is the ability of a material not to allow a current to flow.

Plastic and rubber are good insulators and are therefore used to cover copper wires to stop the wires from touching each other or from touching us.

A **current flow** in any conductor, no matter how big or small, causes two main effects:

- Current flow causes heat to be generated in the conductor.
- Current flow causes a magnetic field to be created around the conductor.

Each of these effects is both good and bad depending on what the application is.

Heat

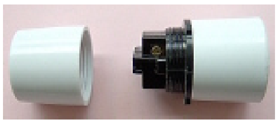
If it is an electric fire then the generation of heat is good - but if the cable has a higher than normal current the heat generated could damage the cable and cause a fire.

Magnetic Field

In the case of an electric motor the magnetic field helps to create the turning power of the motor - but the magnetic field of a phone charger can also interfere with the radio.

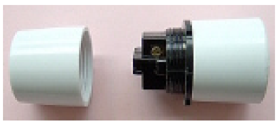
Activity: Materials

Look at the 5 electrical accessories listed below and put a tick in the box if you think a **ferrous**, non-ferrous and/or non metallic material is used (there can be more than one material used):

Number & Name	Accessory	Ferrous	Non-ferrous	Non-metallic
13A domestic **plug top**				
5A one way switch				
Ceiling rose				
13A switch socket				
Lamp holder				

Answers

Materials

Number & Name	**Accessory**	**Ferrous**	**Non-ferrous**	**Non-metallic**
13A domestic plug top			✓	✓
5A one way switch			✓	✓
Ceiling rose			✓	✓
13A switch socket			✓	✓
Lamp holder			✓	✓

One of the biggest disadvantages of ferrous materials is that they can rust or corrode and this is not really something you want in your lighting switch or lamp holder. Rust and/or corrosion will cause damage to the accessory and will eventually cause an open or short circuit.

The table above shows that most of the electrical accessories that we use are made from a combination of non-ferrous and non-metallic materials. Even the switch and the switch socket fixing screws are made from an alloy that is non-ferrous.

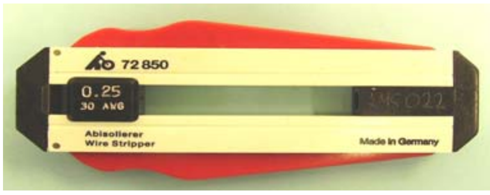
Tools

Wire Strippers

There are many different types of wire strippers that will from strip any type of cable from single core to twin and earth. Usually a wire stripper strips the insulation from the cable leaving the copper conductor exposed. The automatic strippers shown were also known a Yankee Strippers because of their origin.

Wire Strippers

Both these strippers shown in the diagrams are effective and efficient at stripping insulation.



Electrician's Knife

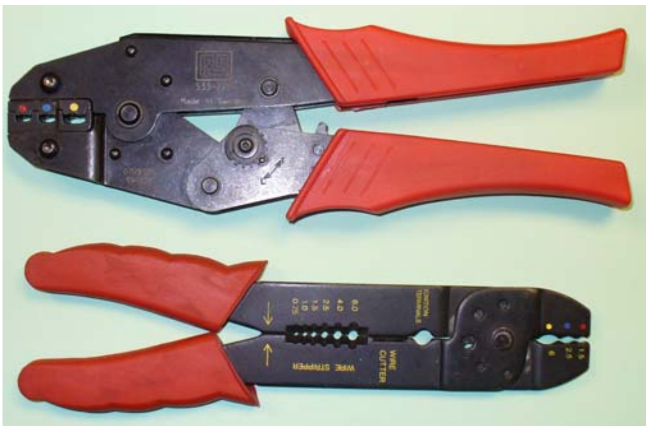
In some instances a specially designed electrician's knife may be used for stripping insulation. A '**Stanley**' knife should never use for this job, it has an extremely sharp blade. An electricians knife is usually quite blunt, to lessen the chance of damage to the copper conductor.

Notice how blunt the knife is.
Please note this knife is a tool and as such would be kept in a tool box, it is an offence to carry a knife.

Crimping Pliers

Crimping is commonly used to clamp (crush in a way) terminals to cable ends. This gives the cable a robust connection that is both electrically and mechanically strong and long lasting.

The crimped end can also be connected and reconnected many times without loss of mechanical strength and electrical conductivity.



Activity: Tool Identification

3

The table below shows a selection of tools – fill in the table with what you think they are called.

Tool	Tool Picture	Tool Name
Tool 1		
Tool 2		
Tool 3		
Tool 4		
Tool 5		
Tool 6		

Answers

Tool Identification Exercise

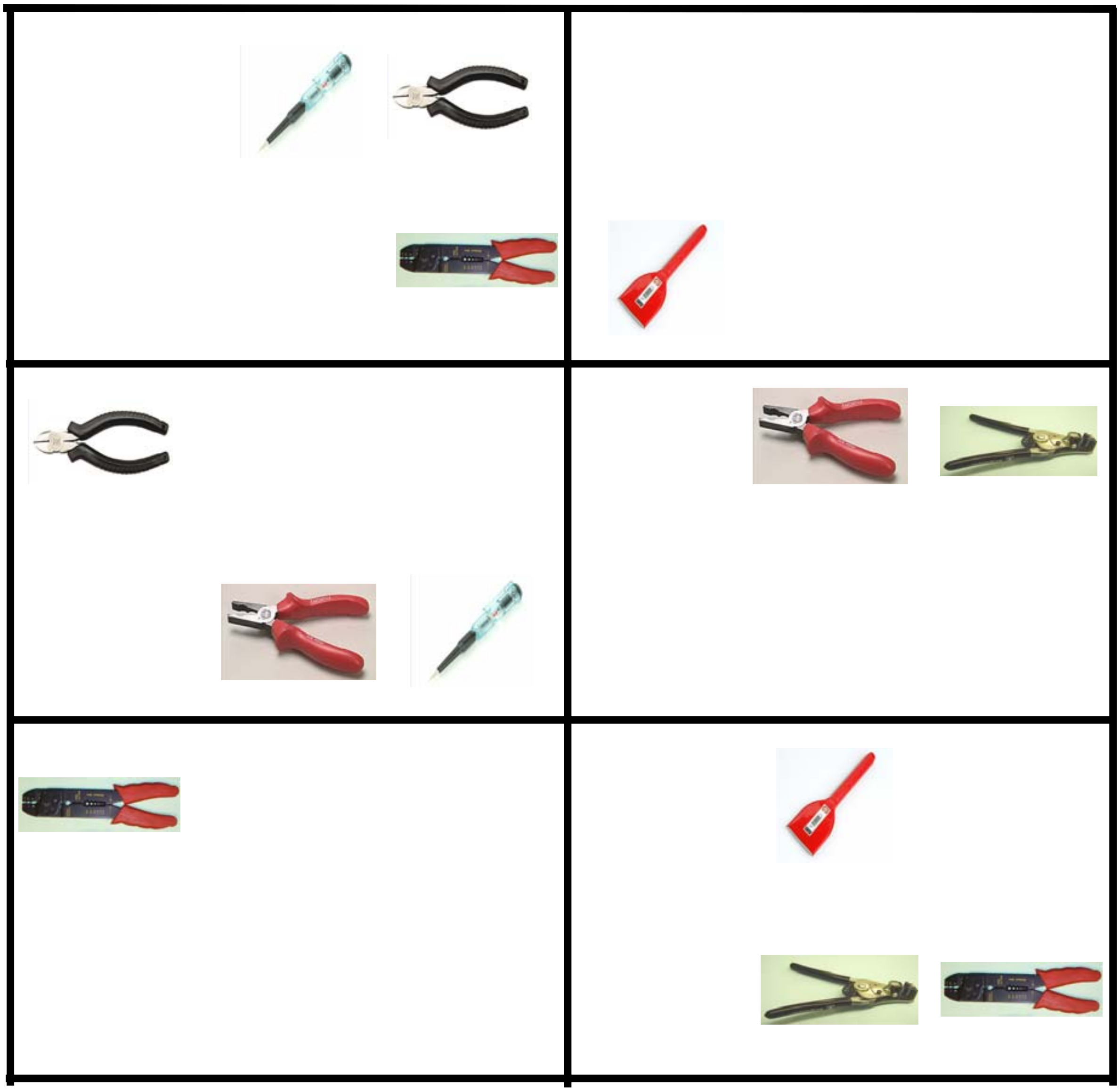
The table below shows a selection of tools – fill in the table with what you think they are called.

Tool	Tool Picture	Tool Name
Tool 1		Crimping Pliers
Tool 2		Electrician's Screwdriver
Tool 3		Cable Strippers
Tool 4		Floorboard Chisel (**Bolster**)
Tool 5		Side Cutters Snips **Cable** Cutters
Tool 6		Combination Pliers

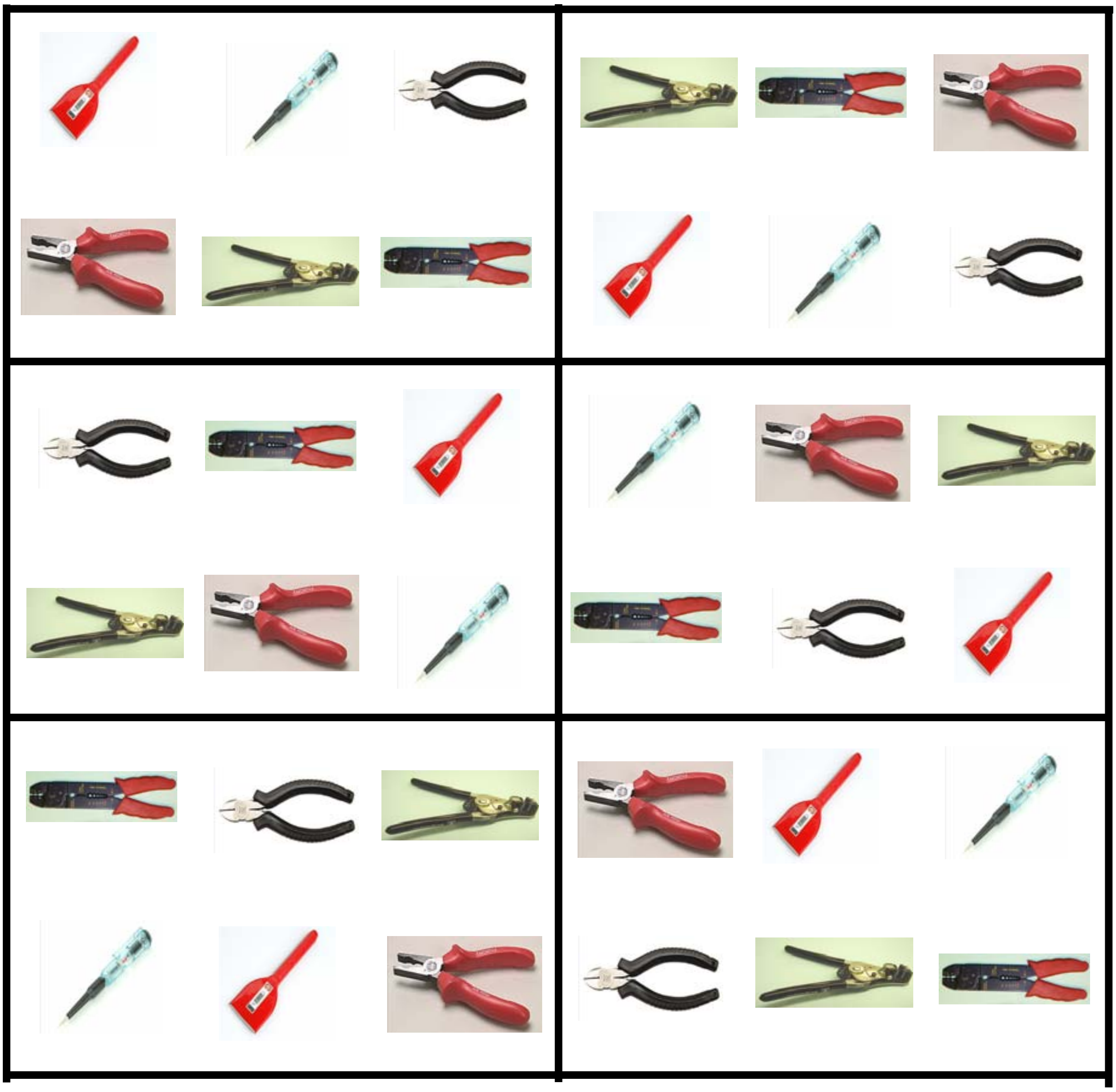
Tool SuDoku

Each group of 6 boxes must contain each of the listed tools but also each line across and up and down must contain each of the 6 tools.

Bolster	Crimpers	Snips	Pliers	Strippers	Screw driver
					



Answers to Tool SuDoku



Bolster	Crimpers	Snips	Pliers	Strippers	Screw driver

Electrical Wires and Cables

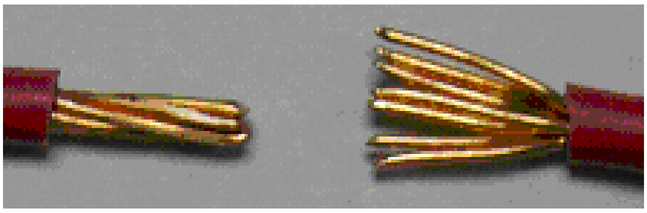
Electrical wires and cables come in many forms and sizes and have a variety of uses.

Wires are **solid** or **stranded**, **insulated** or **un-insulated** conductors.

For most applications, the main requirement of a cable is that it should carry a specified electric **current** between two points in the most economical way. This means we're looking for a material that offers little resistance to the passage of electricity to minimise energy loss along the cable length.

Silver is one of the best materials, but it cannot be used because it is too expensive.

Copper is the most suitable in terms of carrying current and cost – it's cheaper!



Aluminium, which is not as expensive as copper needs a larger size of conductor to carry the same current – so it works out to be more expensive in the end. Aluminium scores over copper mainly in weight saving, because it is lighter than copper.

In the UK, aluminium conductors are usually only used for large fixed-installation power cables for electricity distribution.

Although most wires are made of copper, it is worth remembering most metals will conduct electricity.

Cables are **insulated wires** contained within an **outer insulation** or **sheathing**.

Cable Insulation

To prevent danger from electric shock and possible short-circuits, wires and cables are covered in an insulating material.

In most cases, the cables used in this unit will be insulated with **PVC**.

- polyvinyl chloride (PVC) – clean, easy to use, cheap and resistant to corrosion. This is the most widely used.
- rubber – very cheap but prone to perishing

- polytetrafluoroethylene (PTFE) – expensive but able to withstand high temperatures.

Wires and cables have many uses, for example:

- electrical installations (ring mains, lighting)
- flexible mains (kettle, vacuum cleaner)
- **data transmission** (telephone, computer, TV).

The selection of the electrical cable is dependant on the following factors:

Cable Use **Cable Current** **Cable Voltage** **Cable Situation**

Some of these are shown in the table below:

Cable Use *could be for…………*	Motor Car	House Wiring	Kitchen Appliance
Current that might flow *could be……………*	Small		Large
Voltage that will be applied *could be ………………….*	Low		High
Situation *choice of cable might depend on………………..*	Temperature	Vibration	Environment

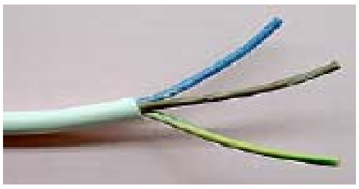
This means that the type of electrical cable used in a motor car would not be the same as the type of cable that would be used in the washing machine even though both cables carry the same current - but **not** at the same voltage.

A co-axial cable that is used to connect the signal to the television is very different from the electrical cable used to connect power to the kettle.

Current Colour Codes

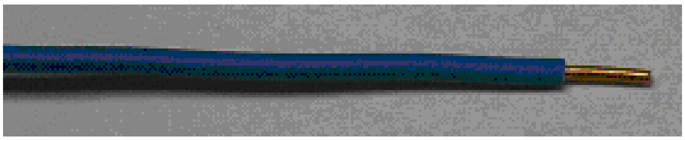
Single Phase:

Protective earth (PE)	Green/yellow striped
Neutral (N)	Blue
Live (L)	Brown



Wire Types

Single strand wire



This type is used where rigidity is required or flexibility is not required. It can be bent, but must not be used in applications where it will be flexed frequently because this would cause it to break.

Multi-strand wire

This is used where a flexible bend in the wire is required or where the wire will be exposed to vibration and is classified by the number of strands in the wire and the diameter (in mm) of each strand.

The difference is not only the voltage or current rating of the wire but also the application, environment, vibration and movement of the wire.

There is no vibration or movement in house wiring so single core, single conductor can be used but usually it would be twin and earth.

Cable Types

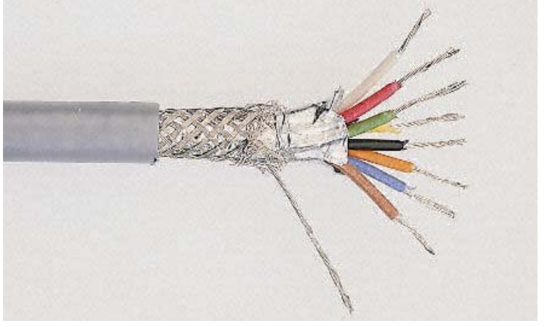
Power cables
Mains voltage is usually 230 Volt in the UK and power cables are designed to carry mains voltages and currents or greater.

Mains cables
Two-core and three-core power cables – usually called mains cables – are used to connect appliances to the public mains supply via a 13A plug and socket. Since mains cables are normally subject to a lot of flexing and movement they tend to comprise of stranded conductors rather than a solid conductor.

Signal cables

Signal cables are made of one or more conductors surrounded by a screen. The screen is braided copper running the complete length of the cable.

It is used to isolate or screen the signal in the central conductor(s) from any outside interference. It also provides security because the screen prevents any radiation from the inner signal.



Multi-core screened cable

Coaxial cable

This is a screened cable with a single solid or stranded conductor surrounded by concentric layers of insulation and screening. Coaxial cable is use to connect an aerial to the input of a television and as connecting leads for test instruments such as oscilloscopes and signal generators.

Coaxial cable

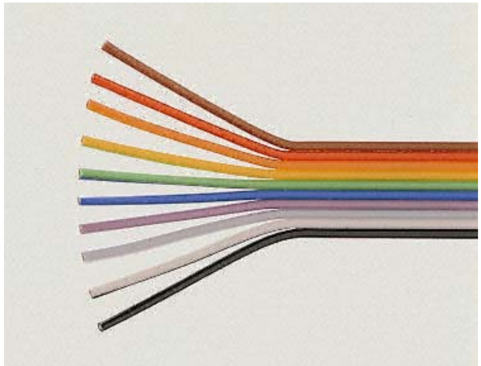
Ribbon cable

Ribbon cable consists of a number of single-core stranded wires joined together lengthways in the form of a flat ribbon.

Ribbon cable provides a quick, simple and cost-effective solution to mass termination. It also has space and weight-saving advantages over other wiring methods.

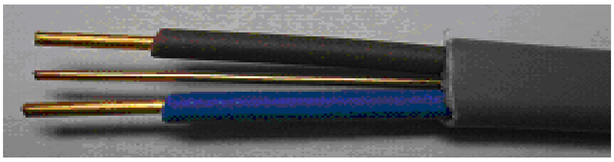
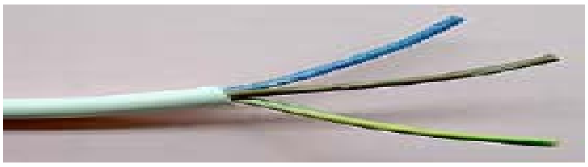
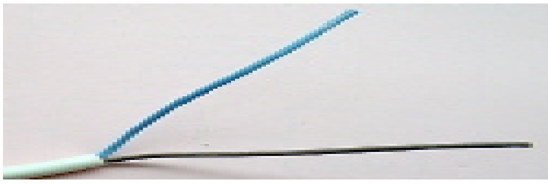
It is ideal for use on computers, peripherals, interfaces, audio and digital equipment.

Not all ribbon cable is multi-coloured.



Coloured 10-way ribbon cable

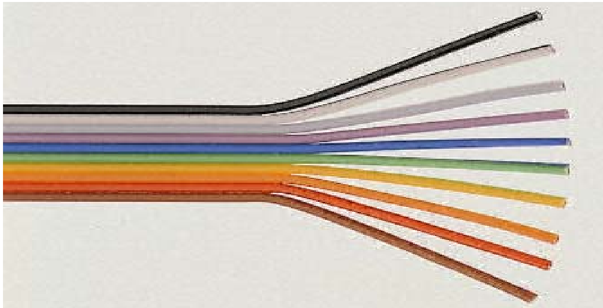
Cable Types and Crimped Terminals

Type	Picture		Use
PVC insulated cables sometimes called Twin and Earth			Mainly domestic and commercial premises; used for lighting circuits and power circuits.
Single core (multi-stranded) - various colours			Industrial use - for circuits where the wiring is subjected to vibration or movement.
Multi-core Flexible cord 3-core			Domestic and commercial use to connect to appliances such as: computers, kettles, X boxes.
Multi-core Flexible cord 2-core			The 2-core version has both its core insulation and its outer sheath made of PVC.
Coaxial			Domestic and commercial use to connect signals to the television.
Crimp Ring			General connections eg: aerospace automobiles appliances industrial control panels electric motors
Crimp Female			
Crimp Male			

Activity: Cable Use

In each of the following, score out the wrong answers:

This type of cable is used for:

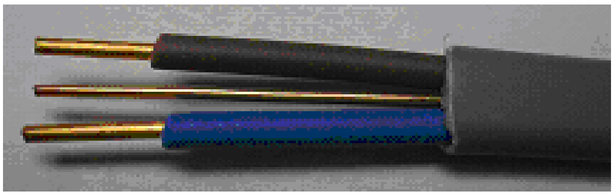


house wiring
television signal
computer
kettle wiring

This type of cable is used for:

house wiring
television signal
computer
kettle wiring

This type of cable is used for:



house wiring
television signal
computer
kettle wiring

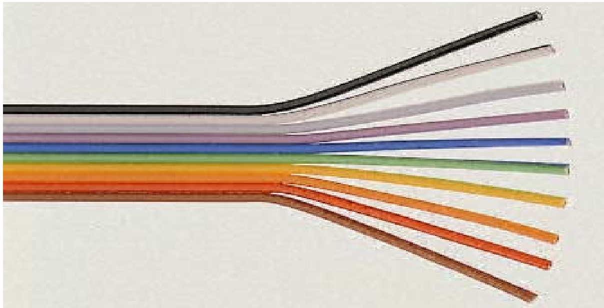
This type of cable is used for:

house wiring
television signal
computer
kettle wiring

Answers

Cable Use

This type of cable is used for:

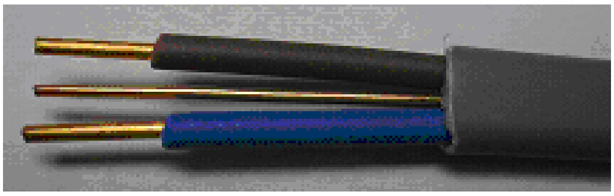


computer

This type of cable is used for:

television signal

This type of cable is used for:



house wiring

This type of cable is used for:

kettle wiring

Domestic Circuits

Lighting

The most common lighting circuits are:

- one way lighting
- two way lighting.

One way Lighting

One way lighting is where a light is switched on and off by one switch only.

A bedroom is usually a common example of a one way lighting circuit. The switch is close to the door and is switched on in the way in and switched off in the way out.

Two way lighting

Two way lighting is where a light can be switched on in one place and switched off in an other place.

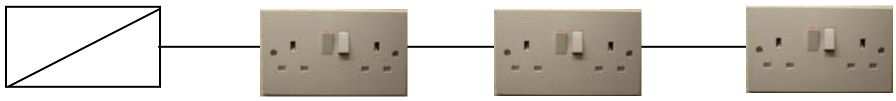
A stairway is a common example of a two way lighting circuit. The light can be switched on at the bottom of the stairs and switched off at the top of the stairs or vice versa.

Power Circuits

Power circuits in the UK are normally **ring** or **radial**.

Radial Circuit

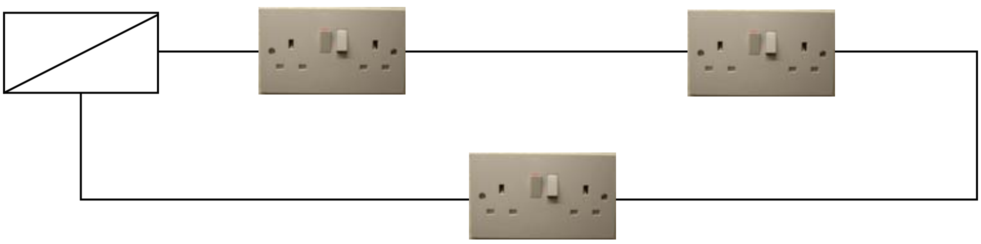
A **radial circuit** is where power is transmitted from the supply to the first socket then to the second, to the third etc and terminates at the last socket.



Radial Circuit

Ring Circuit

A ring circuit is where power is transmitted from the supply to each socket then is connected back to the supply.



Ring Circuit

The ring circuit allows more power to be safely supplied to the circuit using the same cable size as a radial circuit.

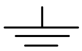
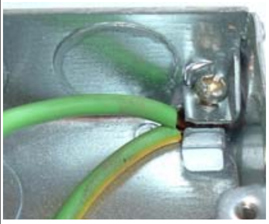
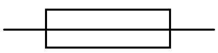
Electrical Symbols

A circuit diagram, sometimes called a **schematic**, is a pictorial representation of an **electrical circuit**. It shows in simplified form the different components and the cables that connect the components. The schematic of the components and cables does not correspond to the physical location. The use of symbols simplifies the schematic and helps to reduce the size.

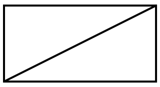
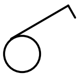
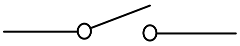
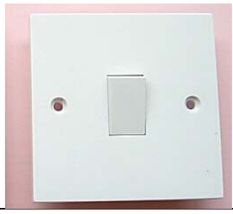
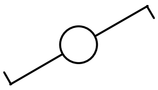
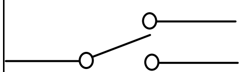
To keep the schematic as simple as possible, instead of drawing the actual component, a symbol that represents the component is used. The British Standards/European Norm (BS EN) is the reference used for most graphical symbols.

Symbols that would be used in electrical schematics are shown in the tables below:

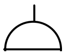
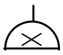
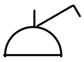
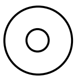
Installation Schematic Symbols (with pictures)

Name/Symbol	Picture	What it does
Earth 		An earth point for a component or circuit.
Fuse 		A safety device to break the circuit if a fault occurs that results in a higher than normal current flow.
Lighting point or lamp 		A lighting point usually in the centre of a room.

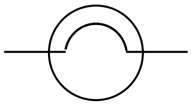
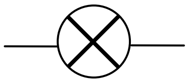
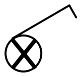
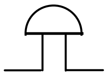
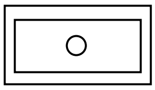
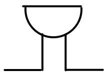
Installation Schematic Symbols (with pictures)

Name/Symbol	Picture	What it does
Main control or intake point 		In most domestic installations this would be the consumer unit, which is where all circuits start and end.
Single pole one way switch  Single pole one  way switch	 	Simple on–off switch for a lighting circuit.
Two way switch  Two way switch 	 	This lighting circuit would be used in a corridor or stair so that it can be switched on and off at two different locations.

Installation Schematic Symbols (with picture)

Name/Symbol	**Picture**	**What it does**
Power Socket 		A simple socket outlet
Power Socket with power indicator 		The pilot light is usually red and illuminates when the socket is in use.
Power Socket with Switch 		Socket outlet with a controlling switch.
Push button 		A doorbell is a prime example of a push button.
Single fluorescent lamp 		A fluorescent light unit.

Other Installation Schematic Symbols (without pictures)

Name	**Symbol**	**What it does**
Twin fluorescent lamp		A twin fluorescent light unit
Filament lamp		A normal light bulb
Signal lamp		Small light used as a power indicator
Switch with pilot light		It is usual to see a switch with a pilot light on a heater or shower circuit
Electric bell		Creates a warning noise
Fire alarm		Switch to operate fire alarm
Buzzer		Creates a warning noise

Electrical Accessories

The table below shows the physical appearance of some other commonly used accessories:

Common electrical accessories

13A domestic plug-top

The **plug top** has three rectangular brass pins and a moulded plastic body.

It is widely used to connect a range of appliances to the supply through a switch-socket and has a cartridge fuse inside the plug body.

The current rating of this fuse depends on the current taken by its load appliance.

It is important that the correct fuse rating is inserted in these plug-tops since failure to do this means that the appliance is not properly protected.

Fuses

Cartridge fuses (limited to those used with 13A plugs)

Cartridge fuses are found in 13A plug-tops and are manufactured to British Standard BS1362. These fuses come in a variety of current ratings including 2A, 3A, 5A, 10A and 13A.

Their purpose is to protect the appliance and the flexible cord which connects to the appliance. Some appliances, not all, will have internal fuses.

13A switch socket

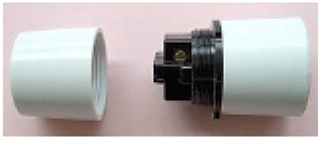
This accessory is used to give a connection between the 13A plug-top and the supply, however it may also include a switch which allows you to control the circuit current.

Ceiling rose

This accessory is used to connect hanging lamp holders to the fixed wiring of an electrical installation. The ceiling rose is usually fixed to the ceilings of most houses, in the centre of the room.

A flexible cord is connected into the terminals of the ceiling rose with the other end of the cord connected to the lamp holder.

Ceiling roses are designed so that any strain caused by a heavy lighting fitting hanging on the cord is not transferred to the electrical terminals.



Bayonet-cap lamp holder

Used to provide a connection between a lamp 'bulb' and the flex.

Electric lamps may be designed to have a 'screw-in' (Edison-screw) connection or a bayonet-cap type of lamp and must be used with a bayonet-cap lamp-holder.

Lamp-holders can be made in either brass or plastic. The brass type will have a connection for an earth conductor and must be used with 3-core flex.

A 2-core flex is normally used the plastic lamp holder.

Batten lamp holder

A batten type lamp holder is designed to be fixed directly on to the ceiling and does the jobs of both the lamp-holder and the ceiling rose. It is used in rooms where the ceiling height is restricted and is too low for a hanging flex.

Batten lamp-holders may be either bayonet-cap or Edison-screw types and are manufactured in either moulded plastic or brass. An earth connection is provided with the brass types.

Bulbs and Heat

Remember all types of lamp holder will get hot when the lamp is switched on. This is particularly true if a high-rated lamp (say 100W) is connected. For moulded plastic lamp holders, the high temperature causes the material to become hard and brittle so that through time it breaks. Lamp holders should be inspected regularly and replaced if damage is noticed. It is recommended that all new bulbs fitted should be energy saving.

Switches

A switch is a simple device which has moveable metal contacts designed to complete the circuit, when in one position, and disconnect the circuit when in the other position. Some modern switching accessories are 'smarter' than this and can actually adjust the amount of light from a lamp.

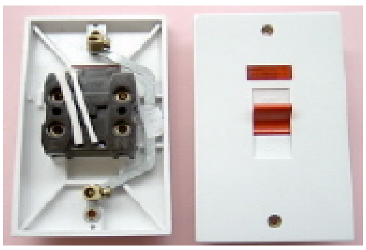
Switches come in many shapes and sizes and are usually named according to their current rating and/or the job they do:

5A one-way switch

These are found in any room or building where the lights need to be switched on and off. They are usually wall-mounted just inside the door of a room so that you can control the light from the door position. A one-way switch means that only one switch is used to control the light.

5A two-way switch

This switch is very similar to the 5A one-way however it allows the light to be controlled from two positions. This is useful in a corridor or stairs where you need to switch on the light from one end and switch it off from the other end.



15A double–pole switch

This switch can handle currents up to 15 A. Double-pole means that the switch disconnects both the live and the neutral conductors of the circuit. This is often needed for safety purposes.

This accessory might be used to control an electric fire or a small electric motor.

Push-button bell switch

This switch or a variety of this switch can be found outside the front door of most houses. It normally operates on 12V and is used to control the doorbell.

5A flexible cord switch

These switches might be found connected in the flexible cord of a table lamp or lamp standard. They can handle currents up to a maximum of 5A. Some of these switches are designed to be foot operated.

3kW electric appliance (eg. kettle) connector

These connectors normally have three slot-type connections to provide for an earth connection. The 3kW rating means that they can handle currents up to 13A.

16A industrial plug-top
These plug-tops have a stronger, more robust construction than domestic types since they are used in situations where they have to cope with industrial conditions.
They have a higher current rating than the 13A plug-top and usually have round brass pins which are shielded by a guard of insulating material.
The insulating guard is normally circular but is designed so that the plug contacts can only be inserted in the socket one-way. This ensures that the correct connections are made with the electricity supply.

Low-voltage bell transformer unit
This provides the front door bell with a voltage of 12v and, since the main electricity supply is at 240V this device is used to reduce this down to the 12V.
This accessory is known as a transformer and it is usually found next to the consumers unit (fuse-box) in the building.
The bell transformer is used to connect the 12V bell to the 240v main supply.

Accessories must only be used for their **designed** purpose.

Activity: Identify accessories

Your tutor will show you a selection of 9 accessories from a larger collection. Each of these will have a reference label attached to it, eg. Accessory 1, Accessory 2, Accessory 3 etc.

You should use the grid below to enter the proper name of each accessory in the space provided against each accessory reference number.

Exercise:

Give the proper name of each of the labelled accessories.

Accessory reference label	Proper name of accessory
Accessory 1	
Accessory 2	
Accessory 3	
Accessory 4	
Accessory 5	
Accessory 6	
Accessory 7	
Accessory 8	
Accessory 9	

Electronic Circuits

Electronics can be divided into two main areas:

- **Analogue** Electronics
- Digital Electronics

Analogue and digital electronics both use the same basic components but the circuits work in different ways.

Analogue

Analogue in this case means continually changing, for instance the heat in the workshop is analogue in nature. The temperature is constantly changing and depends on:

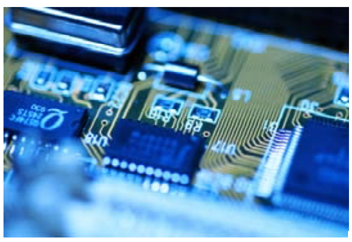
Central heating	on or off
Doors	open or closed
Windows	open or closed
Number of people	large or small
Outside temperature	hot or cold

All of the above factors are continually changing so the workshop temperature is constantly changing.

Most of what happens in the world is analogue in nature and is continually changing, but analogue has problems associated with it and this has led to the development and adoption of digital electronics.

Analogue Components

Analogue circuits are usually made up of components like resistors, **capacitor**s, **inductor**s, diodes, transistors etc.



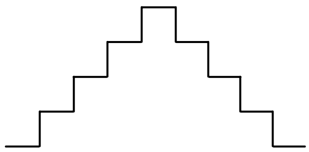
Each component in itself does not do anything magical but when configured in a circuit the right way the results can be amazing.

Digital

Digital has two states, black or white, high or low, on or off, 1 or 0. In digital moving from one state to the other takes no time and happens instantly.

If the heating in the workshop was digital it would be switching from very hot to very cold. The change from very hot to very cold would be rapid.

Think of a mountain, the shape is analogue. The digital equivalent of a mountain is a stepped shape like the pyramids of Egypt.



A digital representation of a mountain

Materials - Electronic Components

Resistors

Resistors oppose the flow of current in a **circuit** and the Ohm (Ω) is the measurement of resistance. Resistors are manufactured from a wide variety of materials, some of the most common are:

Wire

The first resistors would have been made from resistance wire, wound on a ceramic cylinder. Wire-wound resistors are robust, long lasting, big and hot and can have very high power ratings, from 1 or 2 watts to tens of watts. A wire-wound resistor can be so hot it can give you a bad burn so be careful with them. Another disadvantage is the wire-wound resistor is that it is also an inductive coil and will be affected by frequency changes.

Carbon Composition

These resistors are usually made from a mixture of powdered carbon and a ceramic material. These resistors are solid and are usually formed into a cylindrical shape with a connecting wire at each end.

Carbon Film

In this type of resistor a spiral is used to increase the length and decrease the width of the film, which increases the resistance.

This is the most general purpose, inexpensive resistor. The usual tolerance of the resistance value is ±5%. The most common power ratings are 1/8W, 1/4W and 1/2W.
The carbon film resistor has a preferred range, these are:

1.0 1.2 1.8 2.2 2.7 3.3 3.9 4.7 5.6 6.8 8.2

and in any multiple of ten, for instance 1.2Ω, 12Ω, 120Ω, 1.2kΩ, 12kΩ.

1000Ω is 1kΩ, 1000,000 Ω is 1MΩ. 3,900,000Ω is 3.9MΩ etc.

In the case of the 2.2kΩ resistor if the print on the diagram or order form is not good then it could be interpreted as 22kΩ. So decimal points are not used on **circuit diagrams** and the resistor values are written as:
2k2 or 4M7 etc.

Variable Resistors

Variable resistors can be varied to adjust the resistance in a circuit and this might be the volume or the brightness control. Variable resistors can also be preset and this means that they are adjusted at the manufacture stage and should not require adjustment again in the lifetime of the circuit.

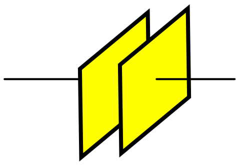
Inductors

An inductor is another name for a coil and most coils are made from copper wire. The copper wire is wound on a cylindrical former and it is the combination of the current flowing, the number of turns of the coil and the material of the former, ferrous or non ferrous, that dictates the inductance of the coil. The inductance of a coil is the ability of the coil to set up a magnetic field. The unit of inductance is the Henry (H) and was named after the American scientist Joseph Henry who discovered electromagnetic induction about the same time as Michael Faraday.

Capacitors

A capacitor is two plates separated by an insulating material called the dielectric. Quite often capacitors are called after the dielectric such as:

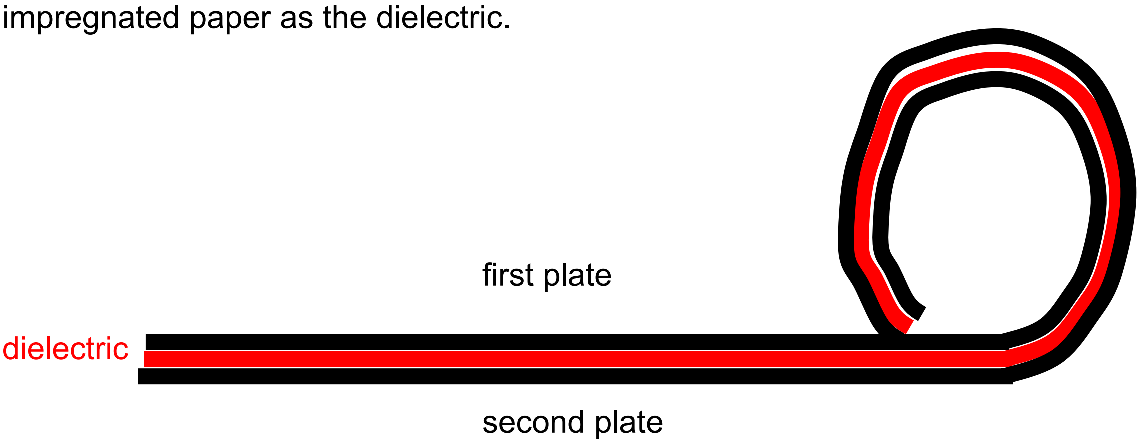
- air
- ceramic
- polyester
- mica
- paper (oil impregnated)



The capacitance of a capacitor is the ability of the two plates to store a charge similar to a battery. The capacitance is dependant on the:

• size of the plates	(bigger the better)
• distance between the plates	(as close as possible)
• dielectric	(good insulator)

Most capacitors are cylindrical. This is because to make the plates as big as possible the plates are long rectangles of foil similar to cooking foil separated by impregnated paper as the dielectric.



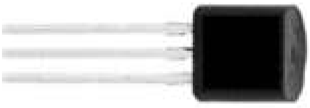
This is then rolled up similar to a toilet roll; hence the cylindrical shape of capacitors.

The unit of capacitance is the **Farad (F)** and is named after Michael Faraday the British scientist who discovered electromagnetic induction.

Semiconductor Material

Semiconductor materials are used a great number of electronic components including:

- diodes
- transistors
- ICs
- audio/visual devices



A semiconductor is a solid material that is neither a conductor nor an insulator.

Silicon and Germanium are both semiconductor materials but the most commonly used is Silicon. Silicon is derived from Silica which is a major constituent of sand and is the second most common element on Earth.

The properties of a semiconductor material can be changed by the addition of certain impurities. This process is called **doping**. When a piece of semiconductor material is doped it can be changed to:

- n-type semiconductor   has a surplus of electrons
- p-type semiconductor   has a deficiency of electrons

A diode is a p-type and n-type material joined together.

A transistor is a **p-type** **n-type** **p-type** material joined together - **pnp**

A transistor is a **n-type** **p-type** **n-type** material joined together - **npn**

An **integrated circuit** or IC is a material with a multitude of p-type and n-type material.

The p-type or n-type semiconductor material can be used as virtually any electronic component so an IC can contains tens, hundreds or thousands of transistors, diodes, resistors, capacitors and inductors.

An IC can also be called a:

- silicon chip
- microchip
- chip

Audio/Visual Devices

Audio Devices

There are a multitude of audio and visual devices and in many cases the materials used for other semiconductor devices are almost the same.

Audio devices would include:

- ICs
- buzzers
- bleepers
- loudspeakers
- microphones.

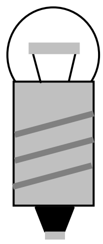
Buzzers and bleepers in electronic circuits use piezoelectric crystals. A piezoelectric crystal is a material that when it is deformed in some way gives a small voltage, but it also works in the converse in that if a small voltage is applied the crystal will emit sound. Piezoelectric crystals are a natural material but the properties have been advanced by the addition of other materials such as quartz.

Certain types of microphones use piezoelectric crystals as the medium to convert sound signals to electrical signals.

In many cases there is little difference in the operation of a microphone (sound to electrical) and a loudspeaker (electrical to sound) and in some electronic circuits a microphone or loudspeaker will be used for both functions. Loudspeakers are generally a lot larger and heavier that a microphone. Most loudspeakers use a magnetic system to convert electrical signals to sound signals. A magnetic system means that coils are used or permanent magnets and this is why loudspeakers are usually big and heavy.

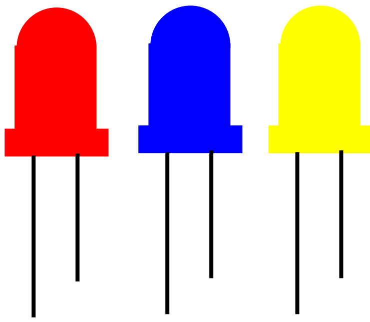
Visual Devices

Visual devices are usually light activated or give off light when operated. These devices include photodiodes, phototransistors, light emitting diodes (LEDs), lamps, light dependent resistors (LDRs)



Photodiodes or phototransistors are packaged with a window, or fibre optic connection, and it is changes of light that determine the operation of the devices.

LEDs



In the case of LEDs the doping material is changed to gallium arsenide (GaAs) which is a mixture of gallium and arsenic. As the diode operates it gives off energy in the form of light.

Light Dependent Resistor (LDR)

The LDR is a resistor whose value changes depending on the amount of light that falls on the resistor. The LDR is made from a high-resistance semiconductor.

In the case of the LDR it is the high-resistance semiconductor that changes with variations of light. The LDR which is made from cadmium sulphide (CdS) can change from around 600Ω under light conditions to over 20MΩ in dark conditions.

Thermistor

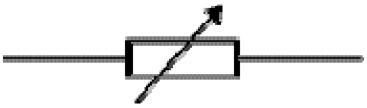
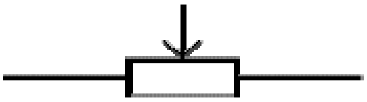
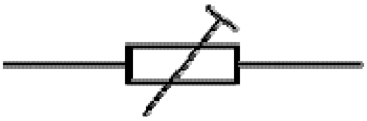
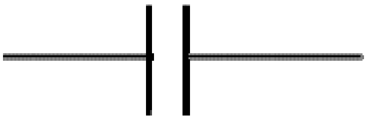
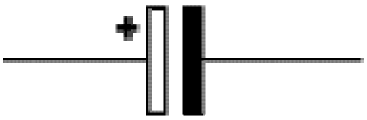
The **thermistor** resistance changes with temperature. In most cases the resistance decreases as the temperature increases. This is called negative temperature coefficient (NTC) but positive temperature coefficient (PTC) where the resistance increases as the temperature increases are also available.

Disc Thermistor

Bead Thermistor

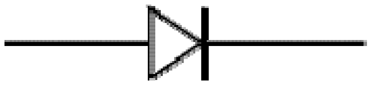
Rod Thermistor

Electronic Symbols

Name	Symbol	What it does
Resistor		A resistor restricts the flow of current in a circuit.
Variable Resistor (Rheostat)		There is no great difference between a Rheostat and a Potentiometer - both are adjustable.
Variable Resistor (Potentiometer)		Both the Rheostat and the Potentiometer are used to control the amount of current in a circuit.
Variable Resistor (Preset)		Same as above but usually factory set and should never normally need adjustment.
Capacitor		A capacitor stores electric charge. A capacitor and a resistor can be used in a timing circuit.
Capacitor - polarised		Same as above but allows a greater charge for the same size.
Variable Capacitor		Capacitance can be adjusted to change timing circuits or to tune circuits.
Trimmer Capacitor		Same as above but usually factory set and should never normally need adjustment.

Diodes and transistors are solid state. Solid state simply means that there are no moving parts and the component can be likened to a solid piece of material.

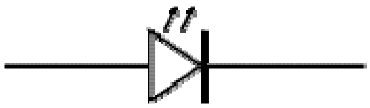
Diode



A diode allows current to flow in one direction only.

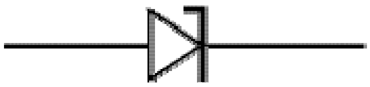
High currents will damage the diode so it usually has a resistor in series with it.

LED
Light Emitting Diode



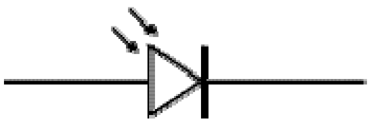
The LED is slightly different to the normal diode. Basically it works the same but gives off light when working.

Zener Diode



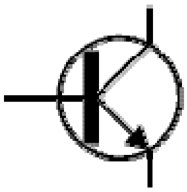
The Zener is a different diode that is always connected in the reverse way. The Zener will then break down at a set voltage level. It is used as a reference voltage source.

Photodiode



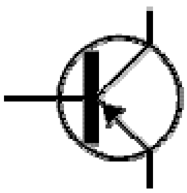
The photodiode conducts in the forward direction when light is allowed to shine on it

Transistor NPN*



A transistor is a solid state switch which can be used to switch circuits or to **amplify** signals.

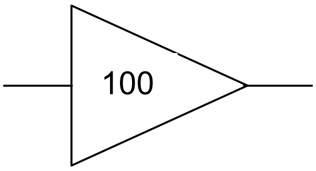
Transistor PNP*



A transistor is a solid state switch which can be used to switch circuits or to amplify signals.
Same not NPN v PNP

* The basic difference between a NPN and a PNP transistor is in the way they are connected to a circuit.

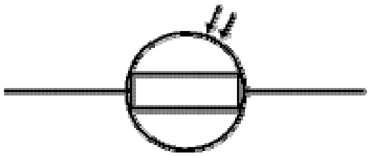
Amplifier



This amplifier has an input signal and an output signal. It is usual for the amplification factor to be written in the block as shown.

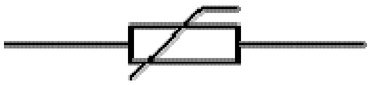
To amplify means to make bigger or larger, so the input signal is made larger by the amplification factor stated. The opposite of amplify is **attenuate** which means to make smaller.

LDR
Light Dependent Resistor



The resistance of the LDR will change drastically from light conditions 400Ω to dark conditions 20MΩ.

Thermistor



The resistance of the thermistor *usually* falls as the temperature rises
20ºC - 700 Ω
40ºC - 300 Ω

Inductor

The inductor is basically a coil and when a current flows it sets up a magnetic field.

Voltmeter

A voltmeter indicates the value of voltage difference between two points in a circuit and is connected into the circuit in parallel. The circuit must be live to get a voltage reading.

Ammeter

Indicates the value of current flowing in a circuit and is connected into the circuit in series. An ammeter is connected into the circuit when not live. Circuit must be switched live to give a reading.

Ohmmeter

An ohmmeter indicates the value of resistance in a circuit or component.
The circuit must not be live.

Activity: Word Search

Word Search

Find the following electrical/electronic terms:

resistor	inductor	switch	capacitor
earth	amplifier	transistor	LDR
socket	analogue	LED	test
diode	thermistor	holder	digital
voltmeter	solder	ammeter	flux
lamp	signal	tools	conductor

D	I	O	R	E	D	F	L	U	X	S	R	O	T	I	C	A	P	A	C
I	R	E	I	T	R	A	N	S	I	I	S	T	O	R	P	E	N	X	Z
O	A	S	S	W	I	T	C	H	N	R	O	T	C	U	D	N	O	C	R
D	R	I	I	W	A	T	C	H	C	R	O	S	E	I	D	E	S	H	J
E	T	S	S	O	C	K	E	T	S	A	V	O	L	T	M	E	T	E	R
T	S	E	T	D	I	G	I	D	G	S	W	E	L	T	O	N	I	N	G
S	T	E	O	V	I	E	A	N	A	L	O	G	U	E	C	A	T	H	P
H	O	L	R	A	M	G	R	A	D	N	T	W	A	R	D	S	E	A	M
R	O	T	S	I	M	R	E	H	T	A	N	P	L	I	F	Y	E	R	A
L	A	M	B	P	F	T	R	A	N	S	I	S	T	O	R	R	S	C	L
A	M	M	E	T	L	D	R	E	H	O	L	L	D	E	R	L	A	H	G
E	R	V	O	L	T	M	A	N	I	M	A	G	E	S	I	G	N	A	L
S	O	L	D	E	R	B	K	I	M	F	L	I	F	I	E	R	S	T	R
A	C	V	B	N	M	O	L	O	S	T	I	A	N	A	P	L	E	A	O
E	A	R	T	H	M	L	A	N	O	D	E	L	I	N	F	R	E	O	T
W	R	Y	S	S	E	I	T	Z	E	U	S	Y	P	D	E	R	K	I	C
E	A	D	A	L	T	R	I	P	H	Y	S	C	I	M	G	E	E	B	U
K	S	F	M	O	O	O	G	X	R	E	T	E	M	M	A	W	A	R	D
K	C	Y	G	O	S	B	I	C	R	O	M	B	E	R	P	H	M	P	N
D	E	L	I	T	G	T	D	R	O	I	T	S	H	O	L	D	E	R	I

Answers

Word Search

Electrical/electronic terms:

- resistor
- earth
- socket
- diode
- voltmeter
- lamp
- inductor
- amplifier
- analogue
- thermistor
- solder
- signal
- switch
- transistor
- LED
- holder
- ammeter
- tools
- capacitor
- LDR
- test
- digital
- flux
- conductor

D	I	O	**R**	E	D	**F**	**L**	**U**	**X**	S	**R**	**O**	**T**	**I**	**C**	**A**	**P**	**A**	**C**
I	R	E	**I**	T	R	A	N	S	I	I	S	T	O	R	P	E	N	X	Z
O	A	S	**S**	**W**	**I**	**T**	**C**	**H**	N	**R**	**O**	**T**	**C**	**U**	**D**	**N**	**O**	**C**	R
D	R	I	**I**	W	A	T	C	H	C	R	O	S	E	I	D	E	S	H	J
E	T	S	**S**	**O**	**C**	**K**	**E**	**T**	S	A	**V**	**O**	**L**	**T**	**M**	**E**	**T**	**E**	**R**
T	**S**	**E**	**T**	D	I	G	I	D	G	S	W	E	L	T	O	N	I	N	G
S	T	E	**O**	V	I	E	**A**	**N**	**A**	**L**	**O**	**G**	**U**	**E**	C	A	T	H	**P**
H	O	L	**R**	A	M	G	R	A	D	N	T	W	A	R	D	S	E	A	**M**
R	**O**	**T**	**S**	**I**	**M**	**R**	**E**	**H**	**T**	A	N	P	L	I	F	Y	E	R	**A**
L	A	M	B	P	F	**T**	**R**	**A**	**N**	**S**	**I**	**S**	**T**	**O**	**R**	R	S	C	**L**
A	M	M	E	T	**L**	**D**	**R**	**E**	H	O	L	L	D	E	R	L	A	H	G
E	R	V	O	L	T	M	A	N	**I**	M	A	G	E	**S**	**I**	**G**	**N**	**A**	**L**
S	**O**	**L**	**D**	**E**	**R**	B	K	I	M	**F**	L	I	F	I	E	R	S	T	**R**
A	C	V	B	N	M	O	**L**	O	S	T	**I**	A	N	A	P	L	E	A	**O**
E	**A**	**R**	**T**	**H**	M	L	**A**	N	O	D	E	**L**	I	N	F	R	E	O	**T**
W	R	Y	S	**S**	E	I	**T**	Z	E	U	S	Y	**P**	D	E	R	K	I	**C**
E	A	D	A	**L**	T	R	**I**	P	H	Y	S	C	I	**M**	G	E	E	B	**U**
K	S	F	M	**O**	O	O	**G**	X	**R**	**E**	**T**	**E**	**M**	**M**	**A**	W	A	R	**D**
K	C	Y	G	**O**	S	B	**I**	C	R	O	M	B	E	R	P	H	M	P	**N**
D	**E**	**L**	I	**T**	G	T	**D**	R	O	I	T	S	**H**	**O**	**L**	**D**	**E**	**R**	**I**

Electronic Components

Resistor

The resistor is a simple component that resists the flow of current in a circuit. The amount of the resistance is dependant on the ohmic value of the resistor. The resistor at the same time creates a voltage drop across it that is related to the current flow and the resistor value.
Resistors are colour coded, mainly because of the difficulties of writing a value on the side of the resistor and the many errors that would occur.
Each colour represents a number according to the following scheme:

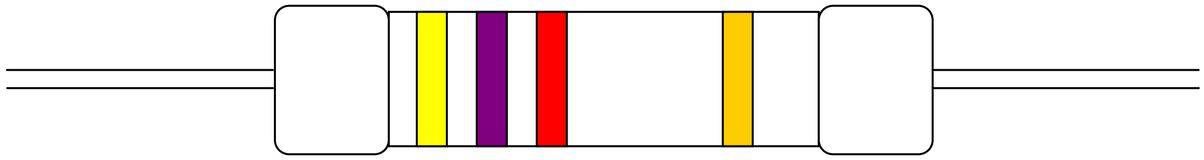
Colour	Number
black	0
brown	1
red	2
orange	3
yellow	4
green	5
blue	6
violet	7
grey	8
white	9

Resistors can have a value that is less than 1 (0.47Ω) but can also have a value in excess of 100,000,000Ω. A range as large as this would mean millions of different values of resistors, so manufacturers have limited the range like the one below:

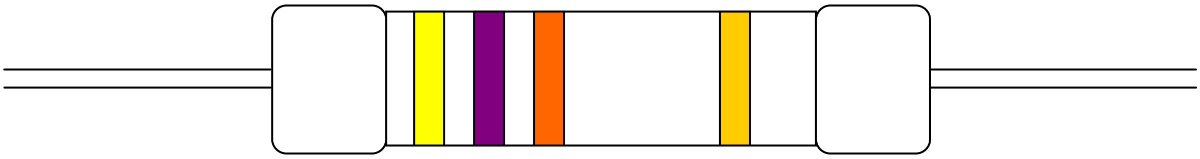
One range of resistors has values of: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82

Each stated value increases by a factor of 10, so for instance:

33Ω	330Ω	3300Ω	33000Ω	330000Ω	or
47Ω	470Ω	4700Ω	47000Ω	47000Ω	

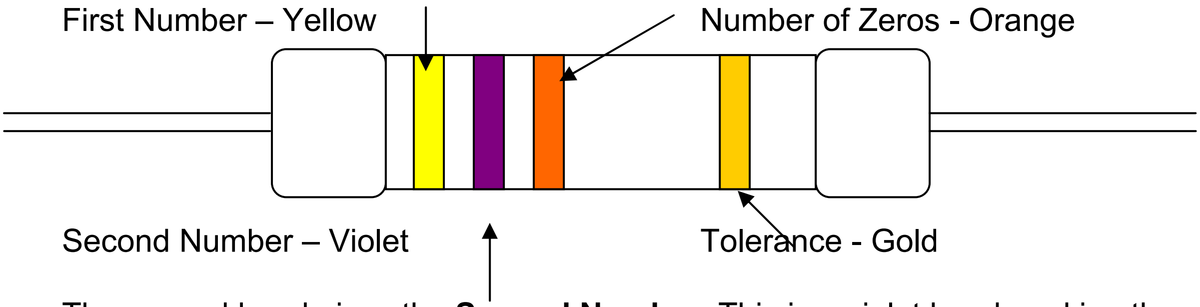


Reading the Value of a Four Band Resistor



The resistor is read this way, with the three colour bands on the left of the resistor and the single band to the right.

The first band on a resistor is interpreted as the **First Number** of the resistor value. For the resistor shown below, the first band is yellow, so the first number is 4:



The second band gives the **Second Number**. This is a violet band, making the second digit 7.

The third band is called the **multiplier** and gives the number of zeros, in this case Orange which is 3.

So the value of the resistor is 47000Ω or 47kΩ (this is pronounced forty seven kay ohm).

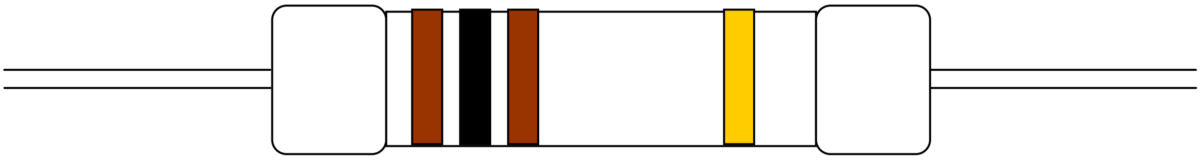
The fourth colour gives the **tolerance**.

The tolerance gives an upper and lower value the resistor must be in, take the following example for a 100Ω resistor:

Tolerance	Colour	Stated Resistor Value	Allowed Upper Value	Allowed Lower Value
±1%	brown	100Ω	101Ω	99Ω
±2%	red	100Ω	102Ω	98Ω
±5%	gold	100Ω	105Ω	95Ω
±10%	silver	100Ω	110Ω	90Ω

Read the value of this resistor.

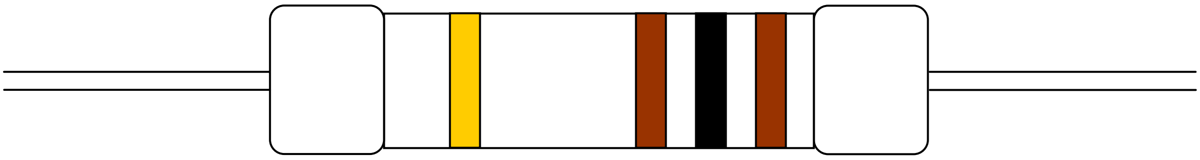
Notice the space between the three bands, then the tolerance band.



Remember to read the resistor value this way round.

Value of resistor:	First	=	brown	=	1
	Second	=	black	=	0
	Third	=	brown	=	0
	Fourth	=	gold	=	±5%
Value of resistor		=	100 Ω		

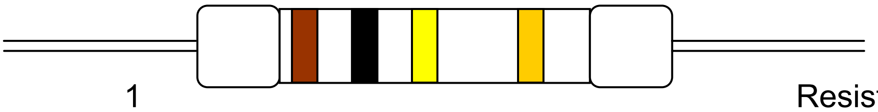
Resistors should **not be read** this way round:



If the value of the resistor was 4700 Ω then this is 4.7kΩ but quite often the point (full stop in this case) can get lost so it would be written this way 4k7Ω.
A lot harder to lose a **k** than a **.**

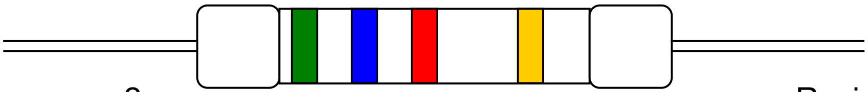
Activity

Read the value of the following resistors:



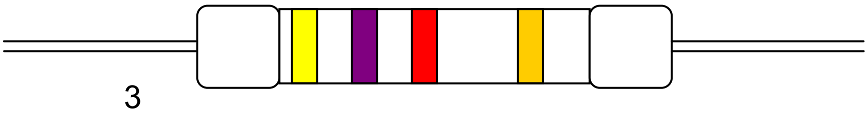
1 Resistor value __________

Brown – black – yellow -- gold



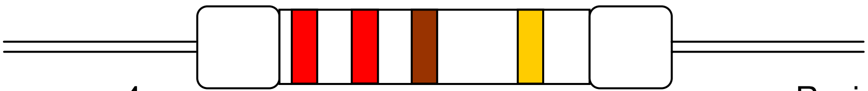
2 Resistor value __________

Green – blue – red -- gold



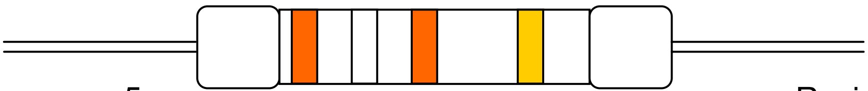
3 Resistor value __________

Yellow – violet – yellow – gold



4 Resistor value __________

Red – red – brown -- gold

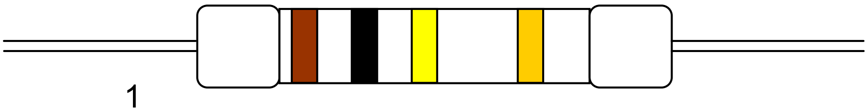


5 Resistor value __________

Orange – white – orange -- gold

Answers

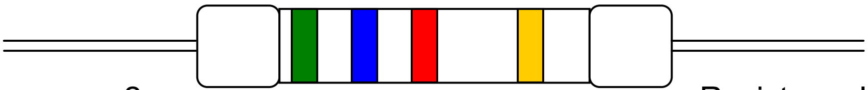
Read the value of the following resistors:



1

Resistor value =100000Ω or 100k Ω± 5%

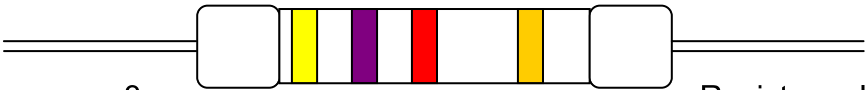
Brown – black – yellow – gold



2

Resistor value = 5600 Ω or 5k6 Ω± 5%

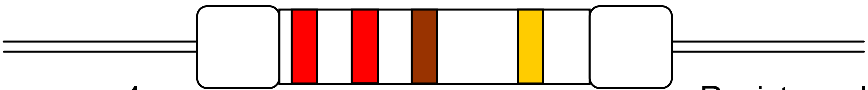
Green – blue – red -- gold



3

Resistor value = 4700 Ω or 4k7 Ω ± 5%

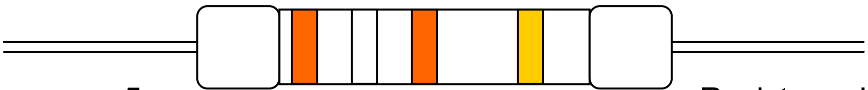
Yellow – violet – red -- gold



4

Resistor value = 220 Ω± 5%

Red – red – brown – gold



5

Resistor value = 39000 Ω or 39k Ω ± 5%

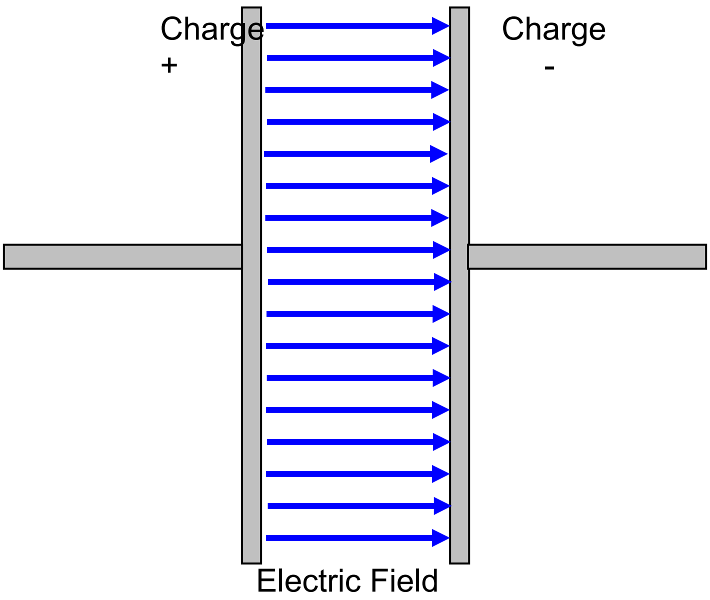
Orange – white – orange – gold

How many did you get? 2 – 3 is very good more than 3 is excellent

Capacitor

A **capacitor** is a device that can store energy, in a similar way to a battery but the capacitor stores energy in the shape of an electrical field.

A capacitor, in its simplest form, has two separate plates and energy is stored by electric charges of equal magnitude, but opposite polarity, build up on each plate.



Capacitors are used in electrical circuits to store energy and can be used when charging or discharging. Capacitor properties change as frequency changes and can be used in tuning circuits such as in the selection of radio stations.

Capacitors are also used in circuits where precise timing is necessary. Using a simple formula, the rate of charge or discharge can be accurately calculated in terms of voltage and time. For instance a capacitor may charge to 5V in exactly 10s. This 5V level can then be used to trigger some other circuit to perform some task.

Capacitor Values

The capacitor unit of measurement is the Farad. Unfortunately the farad is very big, so it is usual to see capacitors measured in microfarads (millionths of a farad).

Three prefixes (multipliers) are used, μ (micro), n (nano) and p (pico):

- μ means 10-6 (millionth), so 1000000μF = 1F
- n means 10-9 (thousand-millionth), so 1000nF = 1μF
- p means 10-12 (million-millionth), so 1000pF = 1nF

Capacitor values can be very difficult to find because there are many types of capacitor with different labelling systems!

Inductors

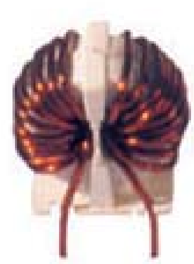
An inductor is a device that stores electrical energy in the form of a magnetic field.

A current flowing through a conductor will always produce two main side effects:

- A magnetic field is set up around the conductor
- Heat is generated

If the conductor is wound on a circular former (coil) then the magnetic field created can be very strong. This strong magnetic field is usually used to make something move.

So the usual use of a coil is to make something move like a:

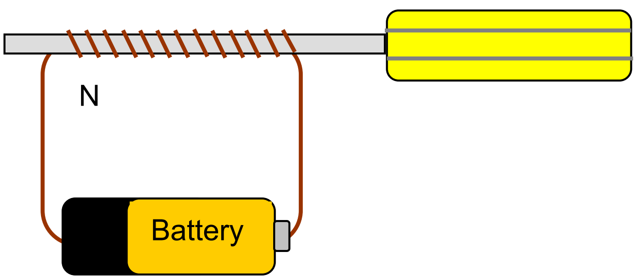


- Relay — a relay is like an automatic switch
- Motor — an electric motor turns electrical power into rotation
- Contactor — a bigger version of a relay
- Solenoid — usually used to push or pull, a diesel engine can only stop when there is no more diesel fed to the engine, so in modern diesel a fuel solenoid is used.

but an inductor can also be used in other ways such as:

- recording an audio tape
- recording in a VCR
- used in a tuning circuit rather similar to the capacitor

Apprentices quite often make a circuit like the one shown and this makes their screwdriver magnetic which can then pick up screws that have been dropped.



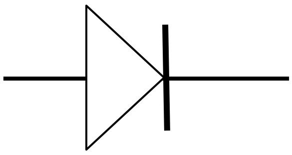
Diodes

In electronic circuits, a diode allows current to flow in one direction only, but blocks current in the opposite direction.

This in itself does not sound impressive but the diode is a mighty component that is used in a multitude of applications.

The two connections of the diode are known as the anode and cathode.

Diode Circuit Symbol

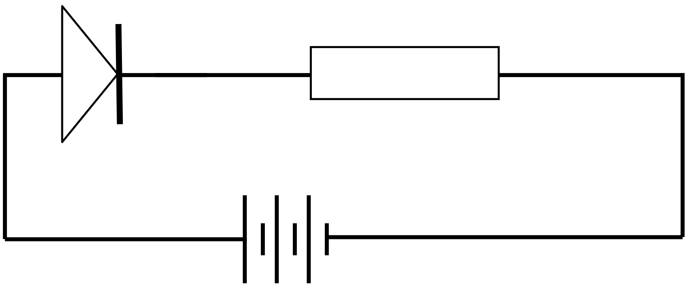


Anode Cathode

Diode Physical Appearance

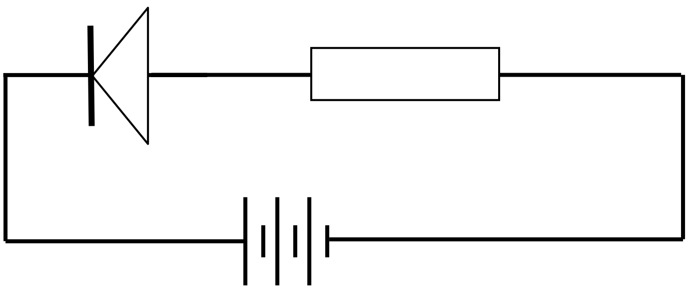
Anode Cathode

The band on the diode indicates the cathode terminal.



In this circuit current will flow

If the diode is connected with the anode to the positive and the cathode to the negative, it is called **forward biased** and current will flow.



In this circuit current will **not** flow

If the diode is connected with the anode to the negative and the cathode to the positive, this is called reverse biased and current will not flow.

Diodes are used in the following:

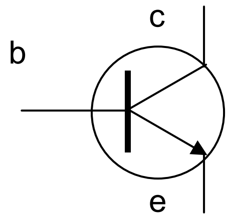
phone charger	games adapter
power supply to an	iPOD
electronic keyboard	VCR
battery charger	television
DVD player	electric shaver
food processor	washing machine

Transistors

Bipolar transistors are divided into two main categories:

npn transistor

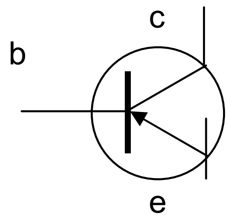
bipolar junction transistor



this is a npn transistor

pnp transistor

bipolar junction transistor



this is a pnp transistor

Bipolar transistors have three terminals:

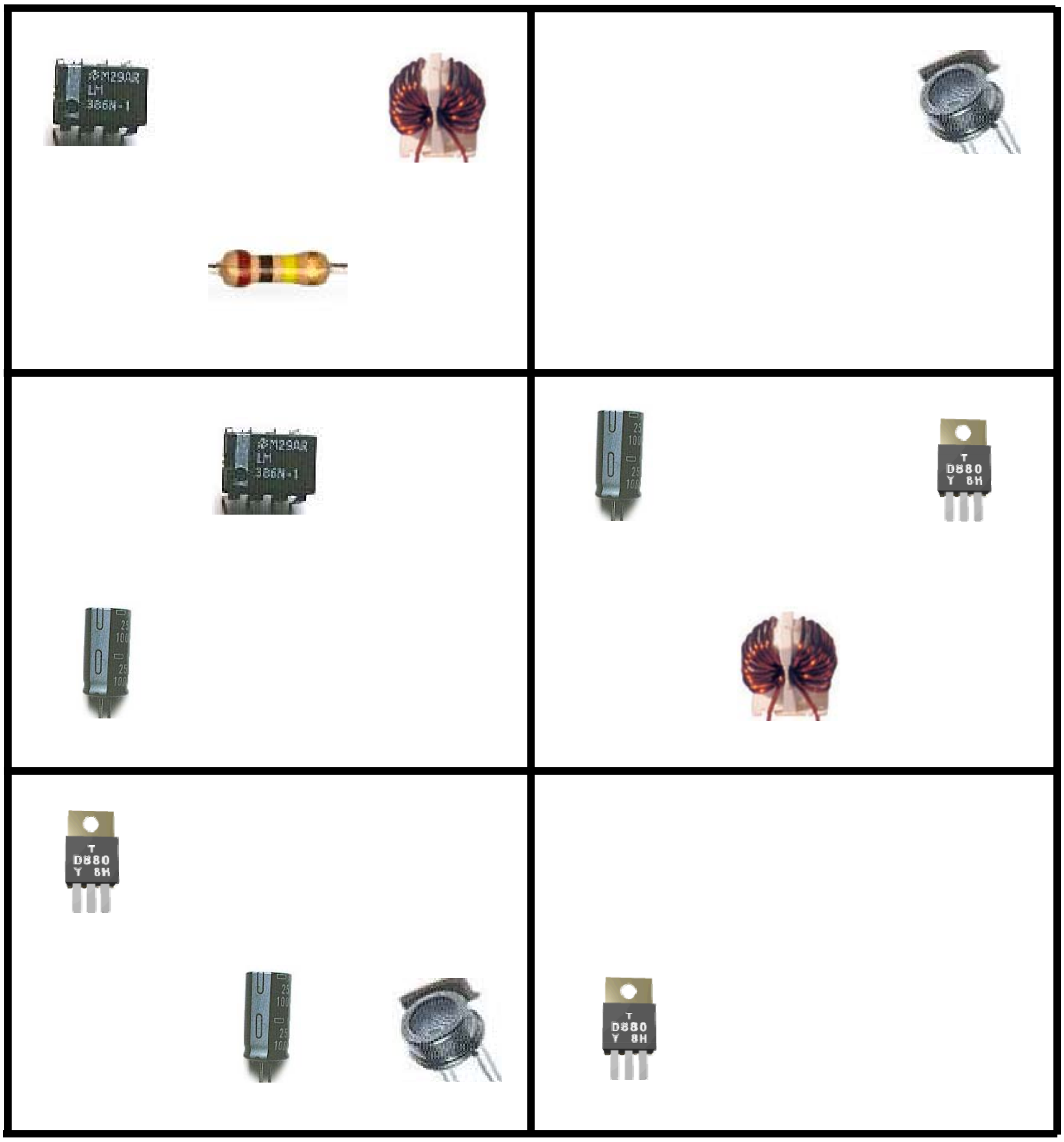
Base	b
Emitter	e
Collector	c

The transistor operates like a solid state switch, where the switch is operated through a signal input to the base. The base signal then controls the amount of current that passes through the collector – emitter connections and therefore the voltage drop. This seems rather mundane but in actual fact the transistor is almost a magical device that can be used in many ways in many applications.
Transistors are mainly used as amplifiers and switches. This does not sound much but the simple transistor is the basis for most of the circuits used in any analogue or digital electronic device such as:

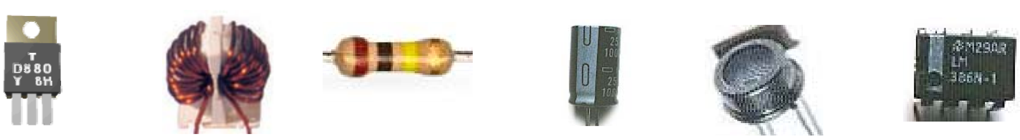
computers	TVs
DVDs	CDs
game consoles	power supplies
chargers	VCRs
phones	iPods
walkmans	MP3s

Component SuDoku

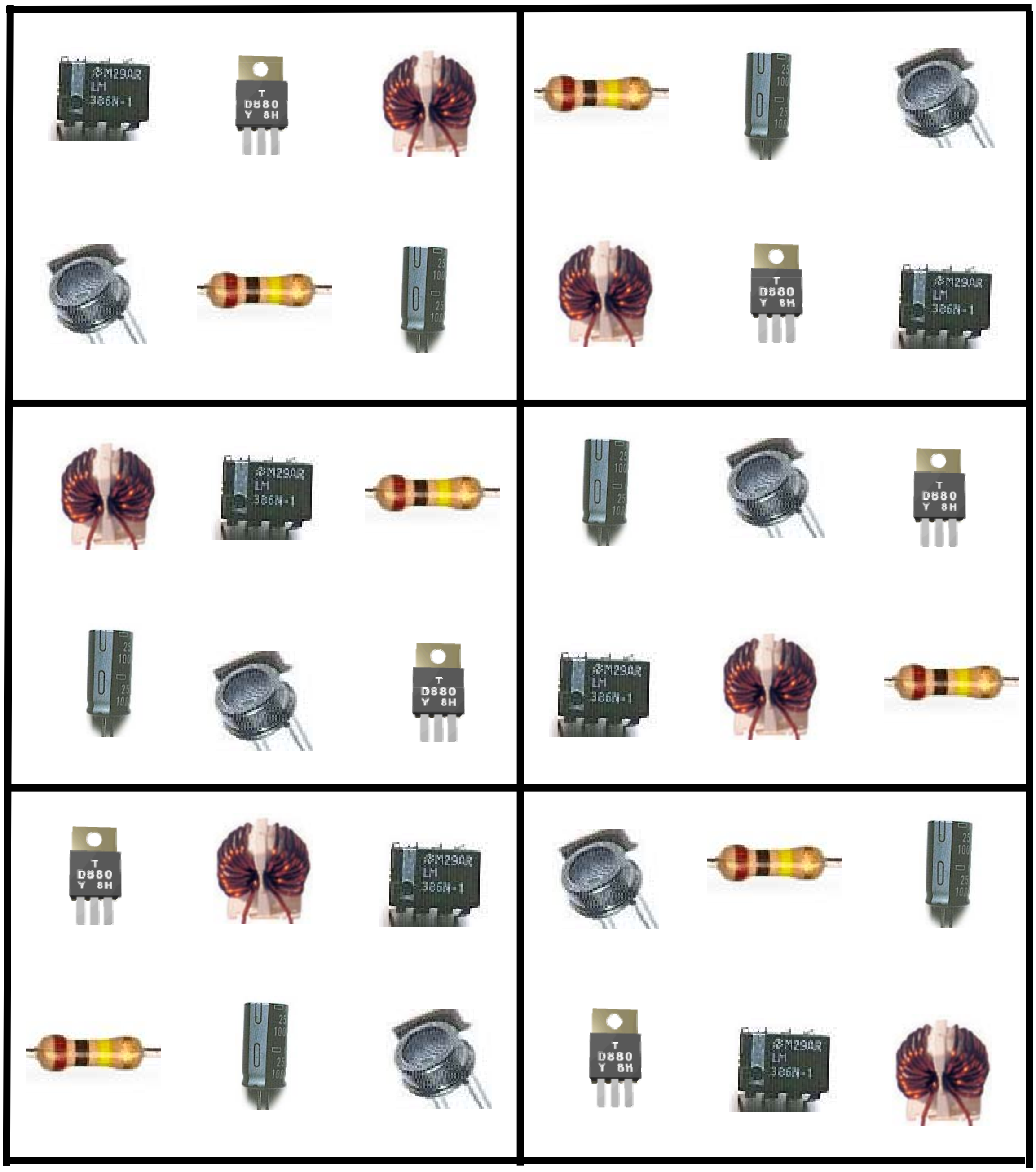
Each group of 6 boxes must contain each of the listed components but also each line across and up and down must contain each of the 6 components.



Transistor Inductor Resistor Capacitor LDR IC



Answers
Component SuDoku



Transistor Inductor Resistor Capacitor LDR IC

Digital Electronics

Digital electronics are commonly used for all sorts of modern technology including games consoles, computers, calculators, watches and mobile phones.

Digital electronics use digital signals that are high or low, true or false, 0 or 1.

Morse code is a digital signal that uses on and off pulses to represent letters of the alphabet.

The digital signal is made up of 1s and 0s but can still be made to carry lots of interesting information, eg. the time, the weather, music, films etc. It can also carry technical data from satellites, space shuttles etc.

Digital uses a simple code of 1s and 0s to represent letters. Let's make a code right now:

Each 1 or 0 is called a bit, so by using 4 bits - 0000 up to 1111
we get 16 combinations – not enough for the alphabet - so let's try 8 bits which should be more than enough for the alphabet.

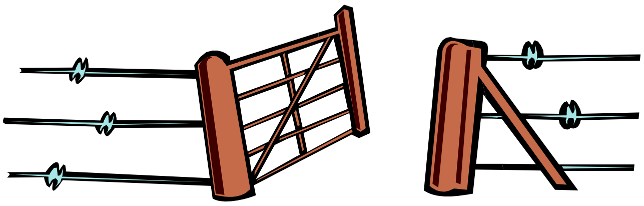
0000 0001 = A
0000 0010 = B
0000 0011 = C and so on

The most common unit of digital electronics is the **logic gate**. **Logic gates** can be combined (thousands of gates) to create really complex circuits which are called digital circuits.

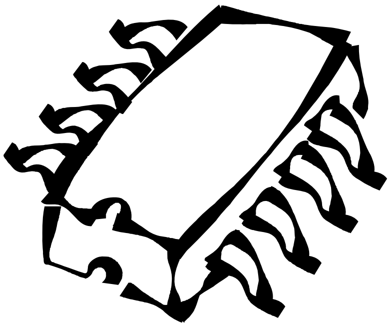
The gate circuit comes in the form of an Integrated Circuit (IC), sometimes called a 'chip'. This chip is also called a silicon chip because they can be made from silicon.

The terms digital circuit, digital system and logic circuit virtually mean the same to an electronic engineer.

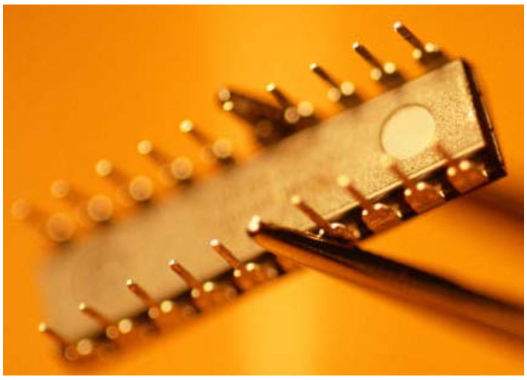
These digital logic gates are all about output and the conditions necessary at the input of the gate, to get an output. The inputs to the logic gates can be termed true or high, this would mean that they have a voltage level that would trigger the gate to work.



Logic Gates

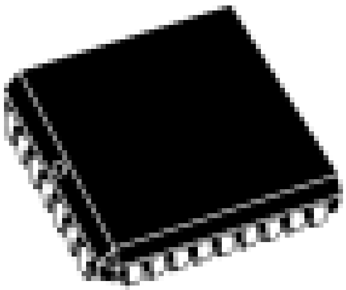


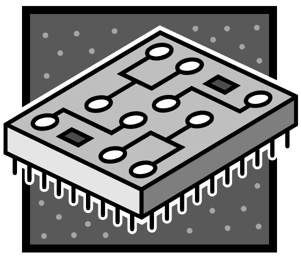
Logic gates are simple electronic circuits that function in a certain way. It is best not to think of the individual circuit components that make a logic circuit work the way it does. It is best to accept that the circuit performs this way, and use the circuit to perform the function required.



All logic gates, except the NOT gate, can have any number of inputs starting from 2 and successively doubling as below:

Number of Inputs Gates	2	4	8	16
	32	64	128	256
	512	1024	etc.	





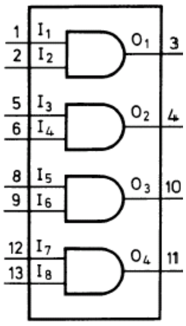
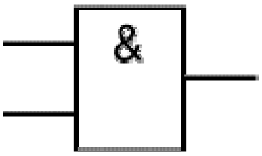
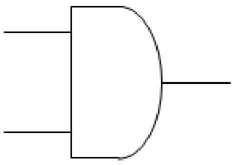
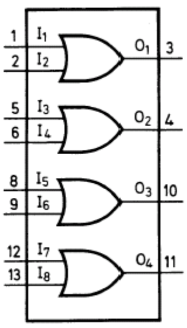
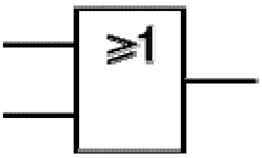
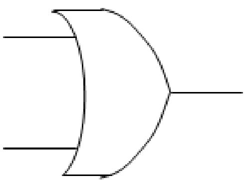
Logic gates are used to design circuits that will perform in a certain way, the way the gate, gates or complete circuit functions can be designed easily by an electronics engineer.

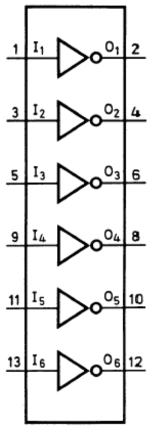
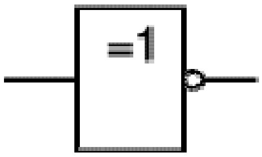
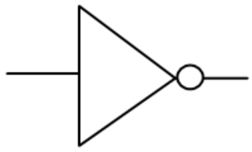
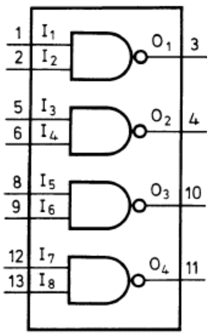
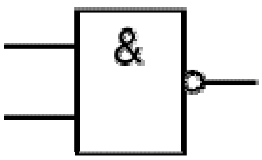
Logic Gates

Two symbols exist for each gate:

- The IEC (International Electrotechnical Commission) symbol
- The ANSI (American National Standards Institute) symbol.

The IEC used to be the British Standard symbol.

<table>
<tr><th>Name</th><th>Symbol</th><th>What it does</th></tr>
<tr>
<td>AND
</td>
<td>
IEC Symbol

ANSI Symbol</td>
<td>An AND gate will give an output only when both inputs are true/high
<table>
<tr><th colspan="3">Truth Table AND Gate</th></tr>
<tr><td>Input A</td><td>Input B</td><td>Output Z</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
</table>
</td>
</tr>
<tr>
<td>OR
</td>
<td>
IEC Symbol

ANSI Symbol</td>
<td>An OR gate will give an output only when either one of the inputs are true/high.
<table>
<tr><th colspan="3">Truth Table OR Gate</th></tr>
<tr><td>Input A</td><td>Input B</td><td>Output Z</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr>
<td>NOT
</td>
<td>
IEC Symbol

ANSI Symbol</td>
<td>A NOT gate only has one input. The NOT gate does the opposite of the input, so if the input is true/high then the output is false/low. If the input is false/low then the output is true/high. Confusing isn’t it.
A NOT gate is also called an inverter.
<table>
<tr><td colspan="2">Truth Table NOT Gate</td></tr>
<tr><td>Input A</td><td>Output Z</td></tr>
<tr><td>0</td><td>1</td></tr>
<tr><td>1</td><td>0</td></tr>
</table>
</td>
</tr>
<tr>
<td>NAND
</td>
<td>
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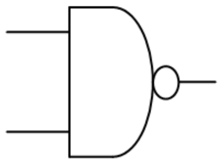
ANSI Symbol</td>
<td>A NAND gate can have two or more inputs. The 'o' on the output means 'not' showing that it is a Not AND gate. The output of a NAND gate is true unless all its inputs are true.
<table>
<tr><td colspan="3">Truth Table NAND Gate</td></tr>
<tr><td>Input A</td><td>Input B</td><td>Output Z</td></tr>
<tr><td>0</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
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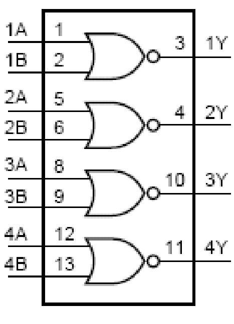
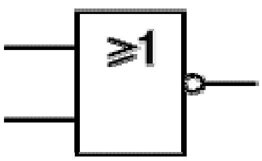
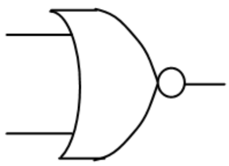
<tr>
<td>NOR
</td>
<td>
IEC Symbol

ANSI Symbol</td>
<td>A NOR gate can have two or more inputs. The 'o' on the output means 'not' showing that it is a Not OR gate. The output of a NOR gate is true when none of its inputs are true.
<table>
<tr><td colspan="3">Truth Table NAND Gate</td></tr>
<tr><td>Input A</td><td>Input B</td><td>Output Z</td></tr>
<tr><td>0</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
</table>
</td>
</tr>
</table>

Integrated Circuits (ICs)

The IC or ‘chip’ was born from the need of having smaller and smaller circuits but these circuits were also required to be more complex, having a greater number of circuits, made from:

- transistors
- resistors
- capacitors

There is a limit to how small a transistor can be made but if the manufacturing process could be changed then more transistors could be made on a single piece of material and that is exactly what was discovered. The complex circuits are etched onto tiny chips of semiconductor material called silicon.

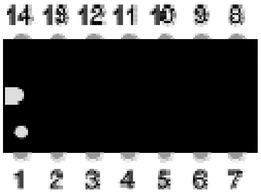
The first ICs counted components such as transistors, resistors and capacitors in tens but modern ICs now count components in the hundreds of millions.

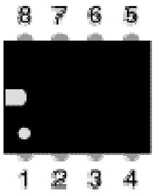
There are many different types of ICs with thousands of circuits but in **analogue electronics** there are certain ICs that provide the basis for many, many circuits.

These ICs include the following:

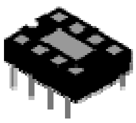
The **741 op amp**

The **555 timer**



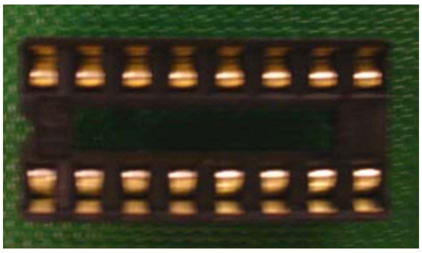


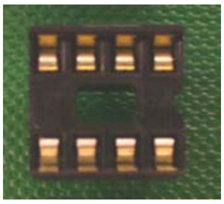
The **7400 logic family**



The connection pins on the IC are numbered from the notch or dot counter clockwise and this is standard for all ICs no matter the number of pins.

Every IC can be damaged by the heat applied when **soldering** so it is normal to use chip holder, usually called a Dual In-Line (DIL) socket. Dual in line simply refers to the pins 1, 2, 3 & 4 being parallel to pins 5, 6, 7 & 8.





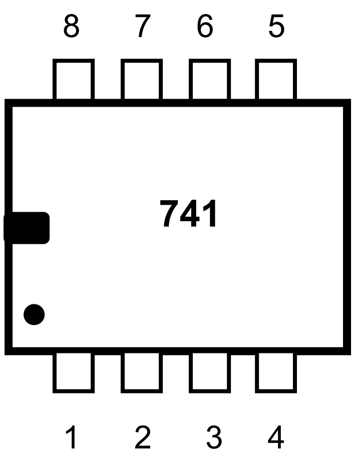
The 741 Op Amp

The 741 op amp is the basic building block for a wide variety of analogue circuits. It is to the analogue electronics industry as the brick is to the construction industry.

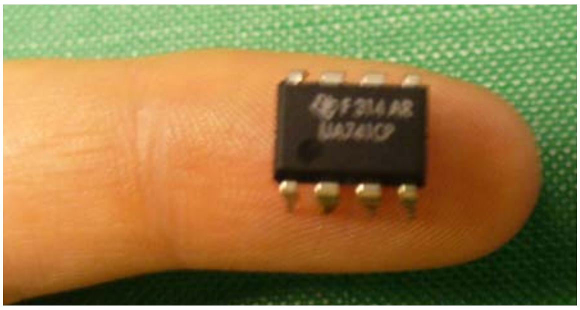
If you were an analogue electronic engineer and a genie popped out of a bottle and gave you one wish then the 741 would be what you would wish for.

Remember an amplifier makes signals larger; the amount that the signal gets larger is called the gain. The gain of the 741 is very high but can be set precisely by the addition of a couple of resistors.

741 Op Amp



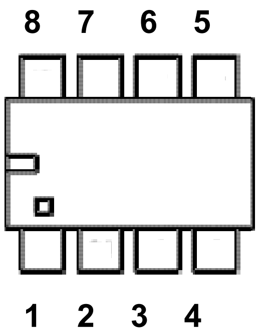
As well as being a powerful and versatile amplifier the 741 op amp can be constructed to give virtually any mathematical function.



The 555 Timer

The 555 timer is one of the most popular ICs ever produced and is the basis for many circuits that require a timer. The 555 timer IC is very reliable and this is reflected in the fact that there are over a billion of these components used in circuits every year.

555 Timer

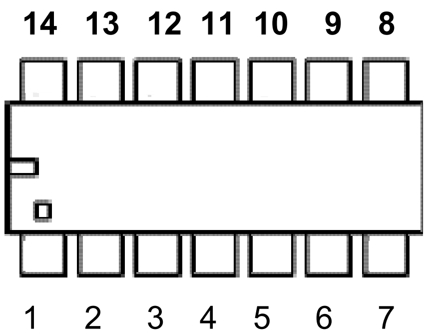


The 8-pin version of the 555 timer is one of the most useful chips ever made and it is used in many circuits. As is the case with most ICs a few external components are necessary to change the IC to perform many circuit tasks. The 555 timer is used to build many circuits, not all of which are timing circuits:

The 7400 Logic Family

The range of the chips that start with the number 7400, go from the 7400 chip all the way to the 747266 chip. Although not all of the numbers in between are used there are still over 250 different logic chips to use in different circuits.

The 7400 Series Logic Family



AND **OR** **NOT**

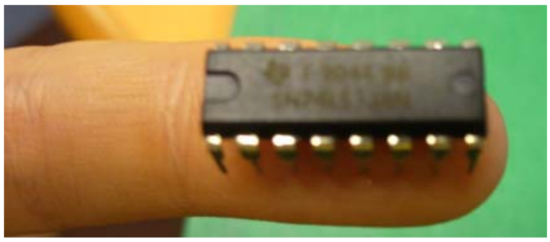
NAND **NOR**

The 7400 family was the first family of IC logic. It was the basic chip on many of the first computers.

The 4000 Series Logic Family

AND **OR** **NOT**

NAND **NOR**



The 4000 series was introduced as a low power alternate to the 7400 series and uses Complementary Metal–Oxide–Semiconductor (CMOS) technology. The 4000 series became more popular than the 7400 because of the low power and higher speed but both have now been superseded by other chip technology.

Soldering

Soldering is a method used in electrical/electronic circuits to connect wires and components.

The **advantages** of soldering are that you get a very good electrical connection with great mechanical strength.

The disadvantages of soldering are that it requires a heat source and there are fumes given off. The fumes and heat source means that there are health and safety implications.

The heat source for soldering is usually from a soldering iron, sometimes called a soldering bolt.

Modern soldering irons are usually electrical. The soldering iron is a simple tool with an **insulated** handle so that it does not get warm. The solder tip is fixed on the element so that it does get warm - warm enough to melt solder.

Solder is a metal alloy that in terms of thermal joining, melts at quite a low temperature. This melting point ranges from around 180°C to 400°C.

Basic solder is a silver-looking metal alloy made from **tin**, silver, copper and other metals such as zinc.

In all electrical/electronic work the solder is now **lead free**.

Soldering depends on heat and cleanliness.

When soldering, the wires or components need to be as clean as possible - so a **flux** is added to the solder to help this.

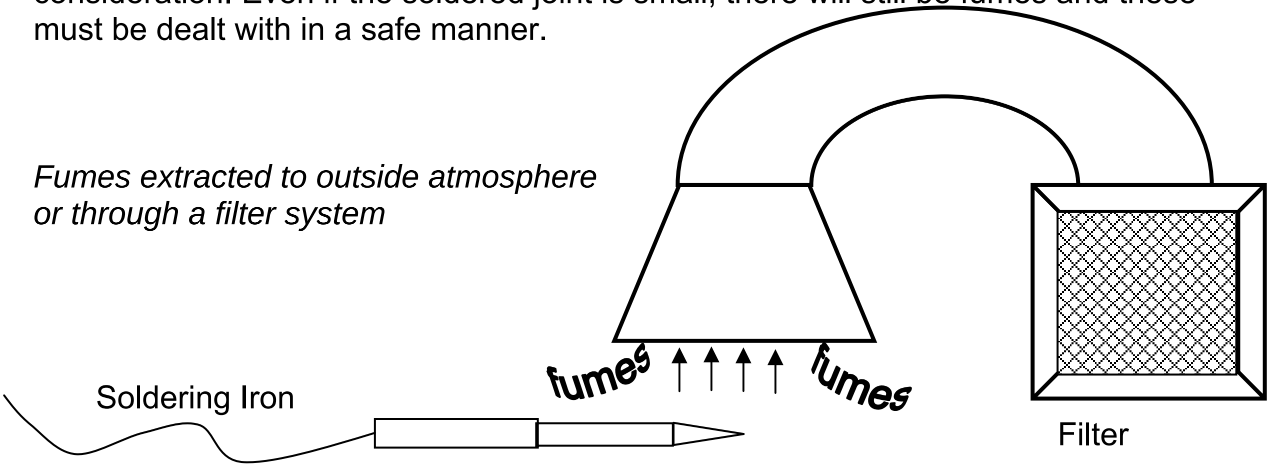
Flux can be compared to a chemical cleaning agent designed to help remove impurities that would affect the cleanliness of the soldered joint.

Soldering requires cleanliness and heat – and practice

Fumes

The mixture of heat and flux gives rise to **fumes**. If the soldering task is large or continuous fumes are evident, then the fumes are a Health and Safety consideration. Even if the soldered joint is small, there will still be fumes and these must be dealt with in a safe manner.

Fumes extracted to outside atmosphere or through a filter system



There are various methods of fume extraction. In all cases, fume inhalation must be avoided.

Solder involves heat and a form of molten metal so it is advisable that safety spectacles or safety goggles are worn when soldering.

Solder splashes on skin are painful, but as long as the splashes are small they should not cause lasting harm.

For most soldering tasks some form of protective clothing should be worn.

The soldering iron must be safely returned to the solder stand to minimise the risk of burns.

Lead Free Solder

All manufacturers are now required to use solder that contains no lead.

Lead Free Solder contains tin, copper, silver, and sometimes bismuth, indium, zinc, antimony and other metals.

Special care is required when soldering components in electronic circuits.

Soldering requires cleanliness and heat – and practice

Soldering Irons

There are many factors to consider when selecting a suitable soldering iron.

Cost

The cost of any tool is always important and this is the case with a soldering iron. A soldering iron can cost from as little as £3 - £4 up to £30 - £40. A soldering iron may also be called a soldering bolt.

Factors other than cost are:

Voltage

Most solder irons are **mains voltage** at 230 Volt, but low voltage 12 Volt or 24 Volt are also available usually as part of a soldering station.

Wattage

Many soldering irons are within the range of 15 watt to 25 watt. It is important to remember that the wattage of the soldering iron does not mean an increase in heat but merely the ability to solder larger joints.

Temperature Control

This simply means that there is a form of temperature regulation. Some cheaper soldering irons just heat but do not regulate the heat. A temperature controlled soldering iron means that the temperature is held at a set temperature rather like a steam iron.

Soldering requires cleanliness and heat – and practice

Activity

You enjoy making small electronic circuits for your family and friends and you have decided you want a soldering iron for your birthday. Your Uncle Andy says he will buy it for you but unfortunately Uncle Andy knows nothing about soldering irons.

You need to help Uncle Andy to select a suitable soldering iron from the following:

Cost

Voltage

Wattage

Temperature Control

State briefly what you would tell Uncle Andy.

Answers

Cost

Prices start from as little as £3, so Uncle Andy can afford to buy you a decent soldering iron - after all it is your birthday.

Voltage

The soldering iron that Uncle Andy will buy you is for use in and around your house or garage so the voltage will be 230V.

Wattage

If you intend to only use the soldering iron for small circuits then a 15W soldering iron would be a good gift but if you intend to solder other bigger circuits and to join wires then perhaps a 25W iron would be better.

Temperature Control

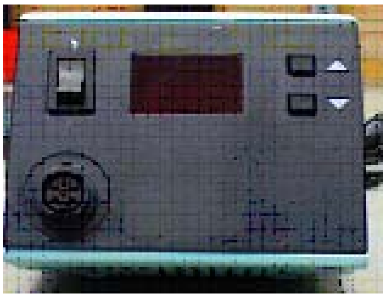
This is where you find out if you are a favourite of Uncle Andy because if the soldering iron has good temperature control then it probably cost that little bit extra.

Next year try for a sunny holiday in Spain for your birthday present.

Go on Uncle Andy is loaded, he can afford it!

Soldering Station

This is complete bench-top control unit into which a special low-voltage soldering iron is plugged. The station shown has adjustable temperature control and a digital readout of the soldering iron temperature.



Solder Iron Variations

The following solder irons are also available:

Gas powered

Battery operated

Solder Gun

The solder gun, looks like a pistol shaped soldering iron. These soldering guns are usually a high wattage and heat very quickly.

Soldering requires cleanliness and heat – and practice

Soldering Techniques

Soldering is a skill that requires practice, the more you practise the better you will become.

Soldering requires cleanliness and heat but it also helps if what you are trying to solder does not move about.

Remember we have two hands, one hand to hold the soldering iron, one hand to hold the solder, leaving no hands left to hold the soldering job. Would you want to hold anything you were soldering? – Ouch!

Helping Hands

This simple piece of apparatus will hold any small soldering job at any position or angle to help you.

However other tools can be used.
In this case a pair of automatic stripper-jaws are used to securely hold the soldering piece. A small vice could also be used.

So firstly secure the soldering job.

Heat

The soldering iron must be allowed to reach its full operating temperature before starting the soldering job. The soldering iron will be used to transfer this heat to all parts to be soldered.

Cleanliness

- Each individual part needs to be clean.
- Clean the solder tip.
- Clean each component.
- Clean the component wires.

Old wires or components can be made ready for soldering by using a small hand-held file; a piece of fine sandpaper or a blunt knife blade to gently clean off the dirt or oxide coating.

The soldering stand shown has a damp sponge that the tip of the soldering iron is cleaned on, not just at the start of the soldering job but constantly.

Dirty wires or components can lead to a 'dry' solder joint. A 'dry' soldered joint can have the appearance of a good joint but internally the electrical connection will not be good. **A good soldered joint will be nice and shiny looking.**

Tinning

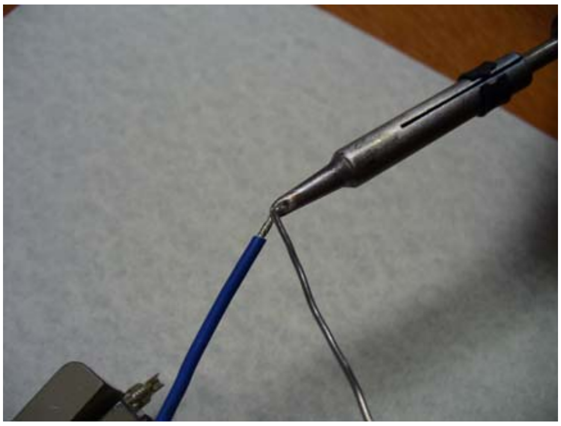
Tinning is the process of applying a thin layer of solder, in this case, to the soldering iron tip. Solder applied is usually wiped off on the damp sponge then the tip is 'tinned' again; the soldering iron should now be ready. This tinning of the soldering iron is also called 'wetting'.

Wires and components to be soldered may also require tinning to enable a quick and efficient soldered joint.

Tinning Wire

The insulation is firstly stripped from the cable.

The many strands or wire may open slightly during this process, so they must be twisted tightly together again.



Heat is applied to the wire through the tip of the soldering iron. It is important to remember that the heat is transferred through the molten solder on the tip of the soldering iron so it must be wet with a small amount of solder and in contact with the wire.

When the heat has transferred and the wire is at the right temperature solder can be applied.

It is not necessary to move the solder along the wire. The solder will be drawn into the wire strands automatically by capillary action.

For most components the longer the heat is applied, the greater the danger of damage to the component. Even wires to be soldered can be damaged by the application of heat for too long, - not to the wire itself but to the insulation of the wire.

Soldering requires cleanliness and heat – and practice

Soldering Components

Tinning is also useful if the wire is to be terminated in a terminal block. The tinned wire is electrically and mechanically stronger and should provide a lifetime trouble-free joint.

Tinning is the first step to the successful completion of a good soldered joint but in many cases there will be more than one wire or component to be soldered together.

In this case it is important that every wire or component is brought to the same temperature so that the solder melts equally into each wire or component giving an excellent joint or bond.

Although it is also important to remove the heat source as quickly as possible it is also important that the soldered joint be kept still and not moved until the solder has cooled or set.

If the hot soldered joint is moved too soon the molten solder will fall away or spread to other areas.

Desolder

This is necessary because components will be changed because of age, circuit modifications or circuit faults.

It is important that the heat is applied quickly and the molten solder removed as quickly as possible.

Solder Sucker

The usual way to remove molten solder is to use a desolder pump. This is sometimes called a solder sucker.

A solder sucker removes the molten solder by sucking it into the barrel of the solder sucker when the plunger is pressed. It works rather like a bicycle pump, but instead of air drawn in on the reverse stroke it is molten solder.

A copper braid can also be used. The braid uses capillary action to draw the molten solder into the braid. The soldered braid is then simply cut away and a fresh piece of braid used for the next time.

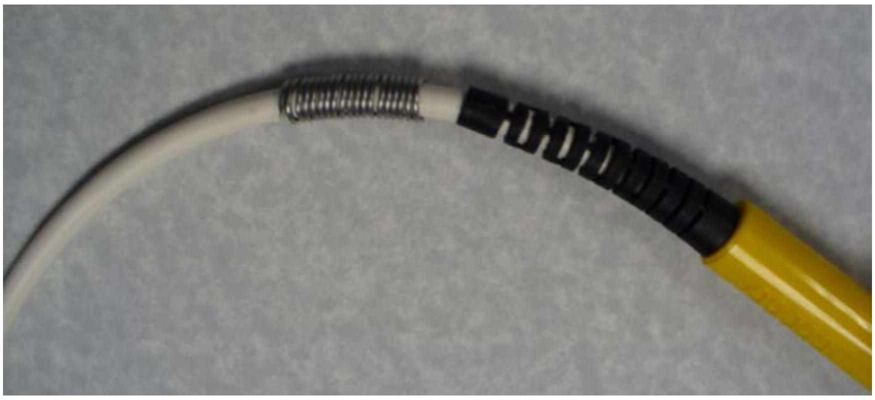
Soldering – A Short Version

1. Clean all parts.
2. Secure the work firmly.
3. ‘Tin’ the solder iron tip.
4. Clean the solder iron tip on the damp sponge.
5. Add a tiny amount of fresh solder to the clean tip.
6. Apply equal heat to all parts of the joint as quickly as possible.
7. When ready apply a small but reasonable amount of solder.
8. Remove heat source and store safely in the solder stand.
9. Do not move the soldered joint, allow a little time for the joint to cool.

Tip

Keep short pieces of solder round the power cable of the solder iron.

This is a good way of storing short pieces of solder and it makes the solder easy to find.



Soldering Knowledge Quiz

Underline the correct answer in the following questions:

What is the sponge on the solder stand used for?

- Keep you cool on hot days
- Clean the solder iron
- Wipe up spilt juice

What is it called when you coat a copper wire with solder?

- Spinning
- Tinning
- Thinning

State another name for a soldering iron.

- Soldering bolt
- Soldering belt
- Soldering coat

Another name for a bad soldered joint is a:

- **Dry joint**
- Wet joint
- Moist joint

Answers to Soldering Knowledge Quiz

What is the sponge on the solder stand used for?

- Keep you cool on hot days
- **<u>Clean the solder iron</u>**
- Wipe up spilt juice

What is it called when you coat a copper wire with solder?

- Spinning
- **<u>Tinning</u>**
- Thinning

State another name for a soldering iron.

- **<u>Soldering bolt</u>**
- Soldering belt
- Soldering coat

Another name for a bad soldered joint is a:

- **<u>Dry joint</u>**
- Wet joint
- Moist joint

Digital Multimeters

A **multimeter** is a test instrument that can usually measure voltage, current and resistance. A multimeter can be analogue or **digital**. Digital multimeters are the most commonly used type of multimeter at the moment. The digital multimeter is also known as a Digital Volt Meter or DVM. Digital multimeters are inexpensive and simple to use and the measured values are easy to read.

Using a digital multimeter to measure voltage means that you will be connecting the meter to a circuit that is live. Live means that the circuit is not isolated or made dead and there is a **real** danger of **shock** or **death** depending on the circuit voltage.

We can never allow **familiarity to breed contempt** because of the very real dangers of injury, **great care** must always be taken when using multimeters.

Polarity

To work out the polarity of a component or a circuit you need to know which connection is positive and which is negative. The correct polarity in terms of the DVM connections is that the red test lead connects to the positive and the black test lead connects to the negative.

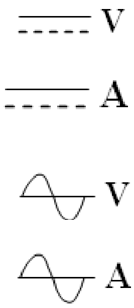
Meters and Circuits

It is very important that any test meter that is connected to measure any physical parameter does not change or load the system which would make all test readings inaccurate and useless to the engineer.

Selector Switch

Digital multimeters usually have a rotary switch that allows voltage, current or resistance to be selected. Digital multimeters are usually auto-ranging which means the correct range will automatically be selected to suit the measured value.

The rotary selector switch allows selection of:



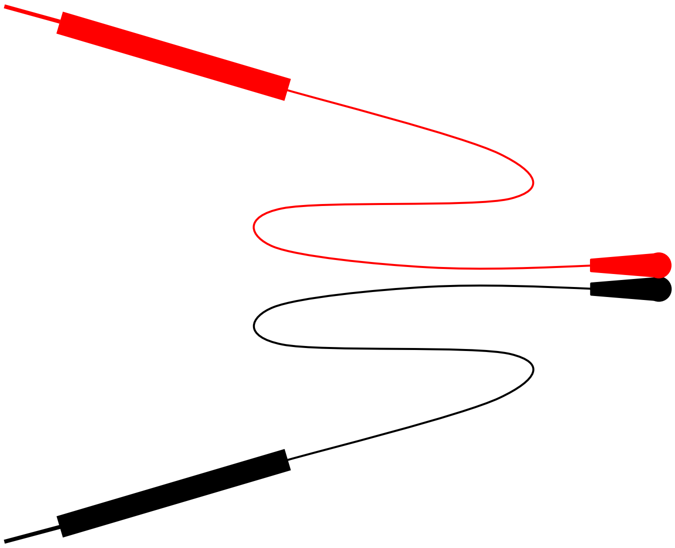
DC Voltage

DC Current

AC Voltage

AC Current A

Resistance Ω



Display

The digital display on the multimeter makes the measured value easy to read and interpret. Many multimeters are analogue and this can make small readings more difficult to interpret.

Connections

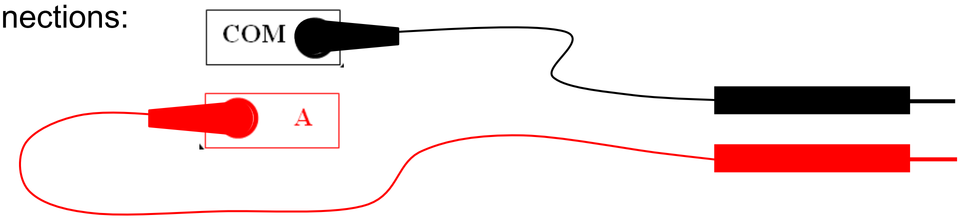
On most digital multimeters there will be two or three connections for the test leads. The test leads are colour coded red and **black**.

The usual connection method is to connect the black lead to the connection marked common or COM for short.

The red test lead is connected to the connection marked V Ω.

In some cases the DVM has three connections and the extra connection is for the measurement of current using connection.

So in this case the test leads would be connected to the following connections:



It is very important that the correct setting (V – A – R) on the DVM is selected each time a measurement is made, or the DVM will be damaged beyond repair. The DVM must always be switched off if not in use.

Measure Voltage

To measure voltage the DVM selector switch is set to Voltage either AC or DC and the test leads are connected in parallel to the relevant component or part of the circuit. To measure voltage, the voltage must still be applied to the circuit so great care must be taken in respect of:

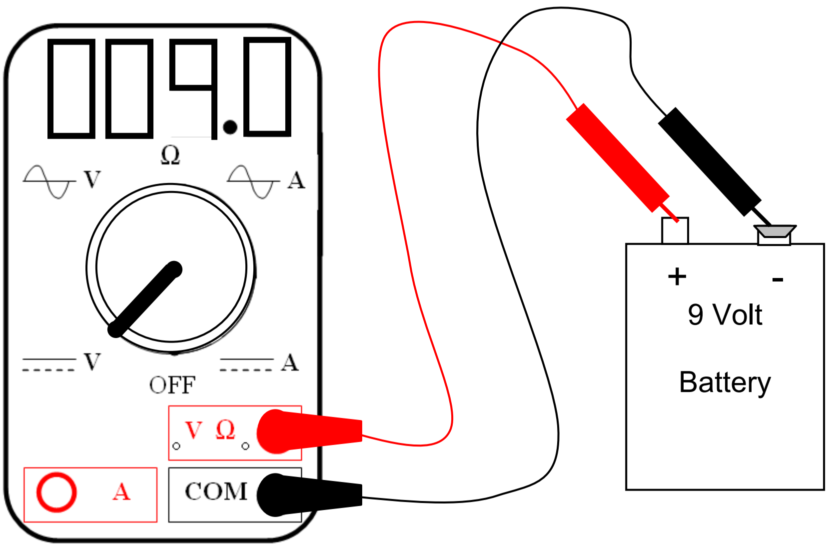
- not touching any part of the 'live' circuit
- not causing a '**short circuit**'.

The **red** test lead should be connected to the **most positive** or highest voltage point.

The **black** test lead should be connected to the **least positive** point or negative or zero voltage point.

If the circuit being tested is a 5V or 9V digital or analogue circuit it would be normal procedure to connect the black test lead to the zero volt connection and reference all other voltage readings to that.

The zero volt connection is sometimes referred to as the **negative rail**, so the black test lead would be connected to the negative rail.



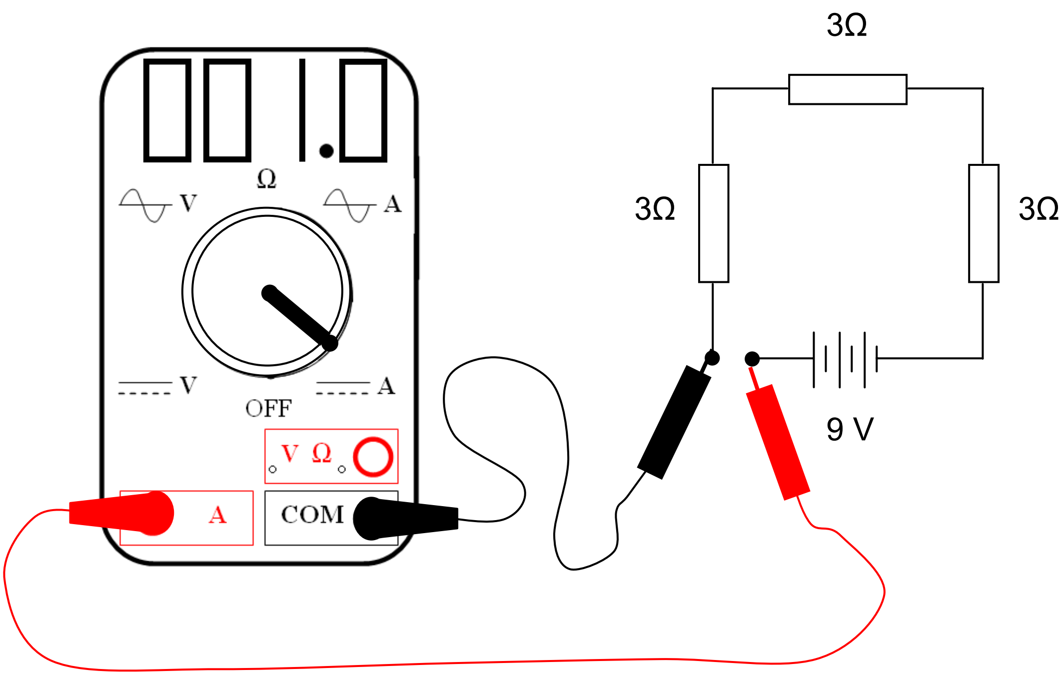
Measuring Current

To measure current the DVM selector switch is set to Current (A) either AC or DC and the test leads are connected in series with the relevant component or part of the circuit.

To measure current, the circuit must be disconnected or isolated. The DVM is then connected into the circuit at the correct location and the power is reconnected.

Great care must be taken in respect of:

- the polarity of the test leads
- the correct setting on the DVM



In this case the voltage applied is 9V.

The total resistance of the three resistors is 3Ω + 3Ω + 3Ω = 9Ω

The current in the circuit by calculation using the formula derived from **Ohm's Law** is:

I = V/R = 9/9 = 1 Ampere

The measured current value = 1 Ampere

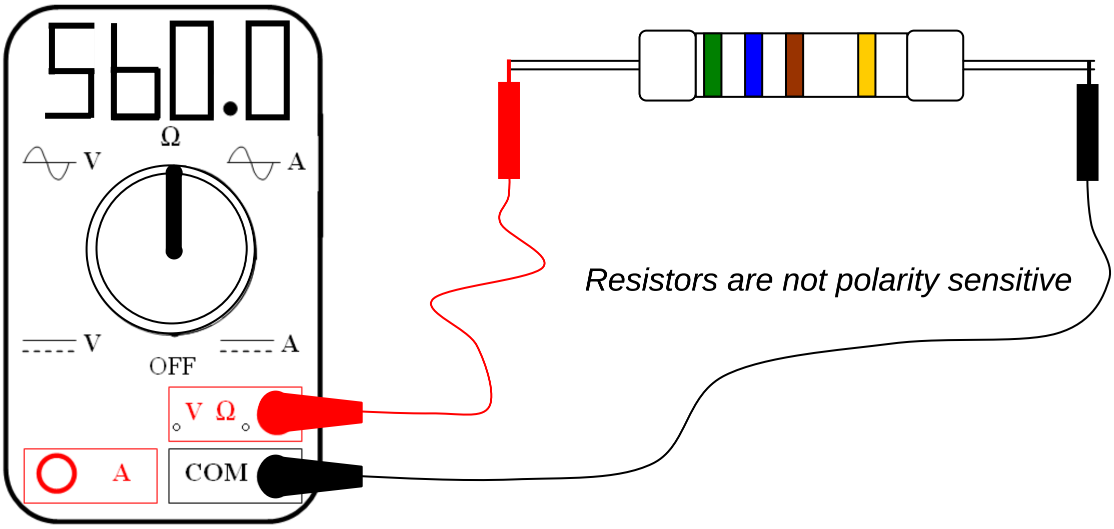
Measuring Resistance

To measure resistance the DVM selector switch is set to Resistance (Ω) and all parts of the circuit must be disconnected from the supply or made dead.

The test leads are connected in across any relevant component or part of the circuit.

To measure resistance, the circuit must be disconnected or made dead, great care must be taken in respect of:

- each component tested must be disconnected from any form of supply
- some components have the ability to hold or retain an electric charge, so this component must be totally discharged before testing.



Continuity Tests

The resistance setting on the DVM can also be very useful for **continuity tests**. Continuity is a test of the connections and cables of a circuit where a circuit does actually exist. If no circuit exists it indicates that a wire is broken, disconnected or there is a bad connection somewhere in the circuit. Most DVMs have a separate setting for continuity tests and these have an audible warning when continuity is good and silence when continuity is bad.

Test Leads

The DVM must be carefully treated to ensure a long and useful life to the engineer, but the test leads are also very important. Remember the test leads are the connection from the DVM to any part of a circuit where the current or voltage may be an unknown quantity because of fault conditions.

These test leads are always in contact with the engineer as well so it is vitally important that the test leads are in good usable condition with no defects or damage in order to protect the engineer from danger. A hand to hand electric shock, with a current path across your chest, is the most dangerous for anyone, so the test leads must be in good usable condition.

It cannot be stressed enough that the condition of the test leads must be very good. Any damage or wear to the test leads means that a new set of test leads must be used and the old test leads disposed of.

Safety Checks

The DVM can be used to check that all the power to a circuit has been switched **OFF** and that the circuit is dead.

However this check as good as it is, assumes that the DVM is operating normally and is giving an indication of zero volt, but what if the meter is faulty and the circuit is not isolated but instead is 'live'.?

So every time the meter is used it must be tested against a known voltage to check the meter is fully operational.

The DVM setting for either Voltage or Current is usually set at a value higher than the supply, for instance if the DVM voltage setting were as follows:

- 200mV
- 2V
- 20V
- 200V
- 600V

If the circuit has a 12V supply and the voltage to be measured is around 1.5V, then the first setting for the DVM would be the 20V range. If the measured voltage is clearly below 2V then that scale setting should be adjusted. In some DVMs the meter will auto range to suit the measured value.

Potential Difference

The potential difference between two points in a circuit, only indicate the difference in voltage at those points and not the overall applied voltage, for instance:

Point A in a circuit the voltage is **231 Volt**

Point B in a circuit the voltage is **230 Volt**

In this case if the DVM were connected to points A and B the DVM would indicate a reading of just 1 Volt but this does not mean that any part of the circuit is safe to touch.

Practice Makes Perfect

There will be tutorial circuits that will have a DC supply of 9V or 5V and it would be a good idea to practise taking different voltage, current and resistance readings. Remember that each time a new reading is required then the rotary switch selected setting must be checked.

Remember:

- A multimeter can measure voltage, current, and resistance and can also be called a Digital Volt Meter or DVM for short.

- To measure voltage the DVM is connected in parallel and this means that the circuit must have the power supply still connected which is potentially very dangerous.

- To measure current the DVM is connected in series and this means that the power must be switched **OFF**, the DVM is then connected to the circuit and so the power is restored.

- Always check the rotary selector switch for the correct setting before measuring any values.

- To measure resistance or continuity the circuit must be isolated from the supply and then checked that all components that could store electrical energy are discharged.

- Multimeters or DVM are designed not to alter the circuit so that measured values are as accurate as possible. The voltmeter has a very high resistance and the ammeter has a very low resistance which means that if the wrong setting on the rotary switch is selected the meter will be damaged probably beyond repair.

DVM Activity

In this activity select the right setting for the DVM by placing a tick beside it.

To measure:				
A DC Current	⎓ V	⎓ A	∿ V	∿ A
A DC Voltage	⎓ V	⎓ A	∿ V	∿ A
An AC Current	⎓ V	⎓ A	∿ V	∿ A
An AC Voltage	⎓ V	⎓ A	∿ V	∿ A

In this activity select the correct option for DVM connection by placing a tick beside it:

To measure DC voltage	connect in series	connect in parallel
To measure DC current	connect in series	connect in parallel
To measure AC voltage	connect in series	connect in parallel
To measure AC current	connect in series	connect in parallel

Answers to DVM Activity

In this activity select the right setting for the DVM by placing a tick beside it.

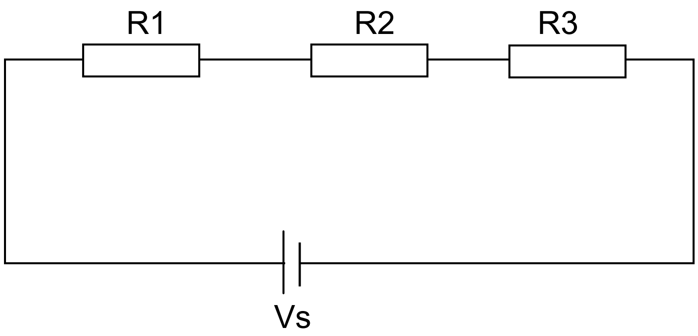
To measure:				
A DC Current	⎓ V	✓ ⎓ A	∿ V	∿ A
A DC Voltage	✓ ⎓ V	⎓ A	∿ V	∿ A
An AC Current	⎓ V	⎓ A	∿ V	✓ ∿ A
An AC Voltage	⎓ V	⎓ A	✓ ∿ V	∿ A

In this activity select the correct option for DVM connection by placing a tick beside it:

To measure DC voltage	connect in series	connect in parallel ✓
To measure DC current	connect in series ✓	connect in parallel
To measure AC voltage	connect in series	connect in parallel ✓
To measure AC current	connect in series ✓	connect in parallel

Activity – Measure Voltage, Current and Resistance

Connect the circuit as shown on either prototype board or stripboard and measure the voltage, current and resistance.



Select suitable values such as:

R1 15Ω

R2 18 Ω

R3 22 Ω

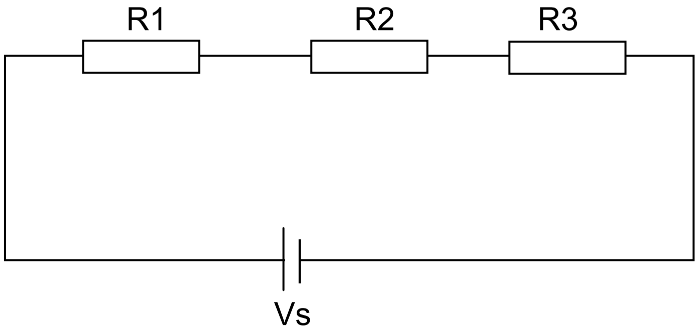
Vs 5V

Complete the table:

	Value
R1	
R2	
R3	
R_{Total}	
Vs	
V_{R1}	
V_{R2}	
V_{R3}	
Is	

Activity: Measure Values

Circuit connected as shown:



Values:

R1 15Ω

R2 18 Ω

R3 22 Ω

Vs 5V

Complete the table:

	Value
R1	15Ω
R2	18 Ω
R3	22 Ω
R_{Total}	55 Ω
Vs	5V
V_{R1}	1.36V
V_{R2}	1.63V
V_{R3}	1.99V
Is	90mA

Notice that the sum of the 3 voltages V_{R1}, V_{R2} and V_{R3} equal the value of the supply voltage V_s.

$\therefore$ Vs. = $V_{R1} + V_{R2} + V_{R3}$

This is very important in circuit analysis

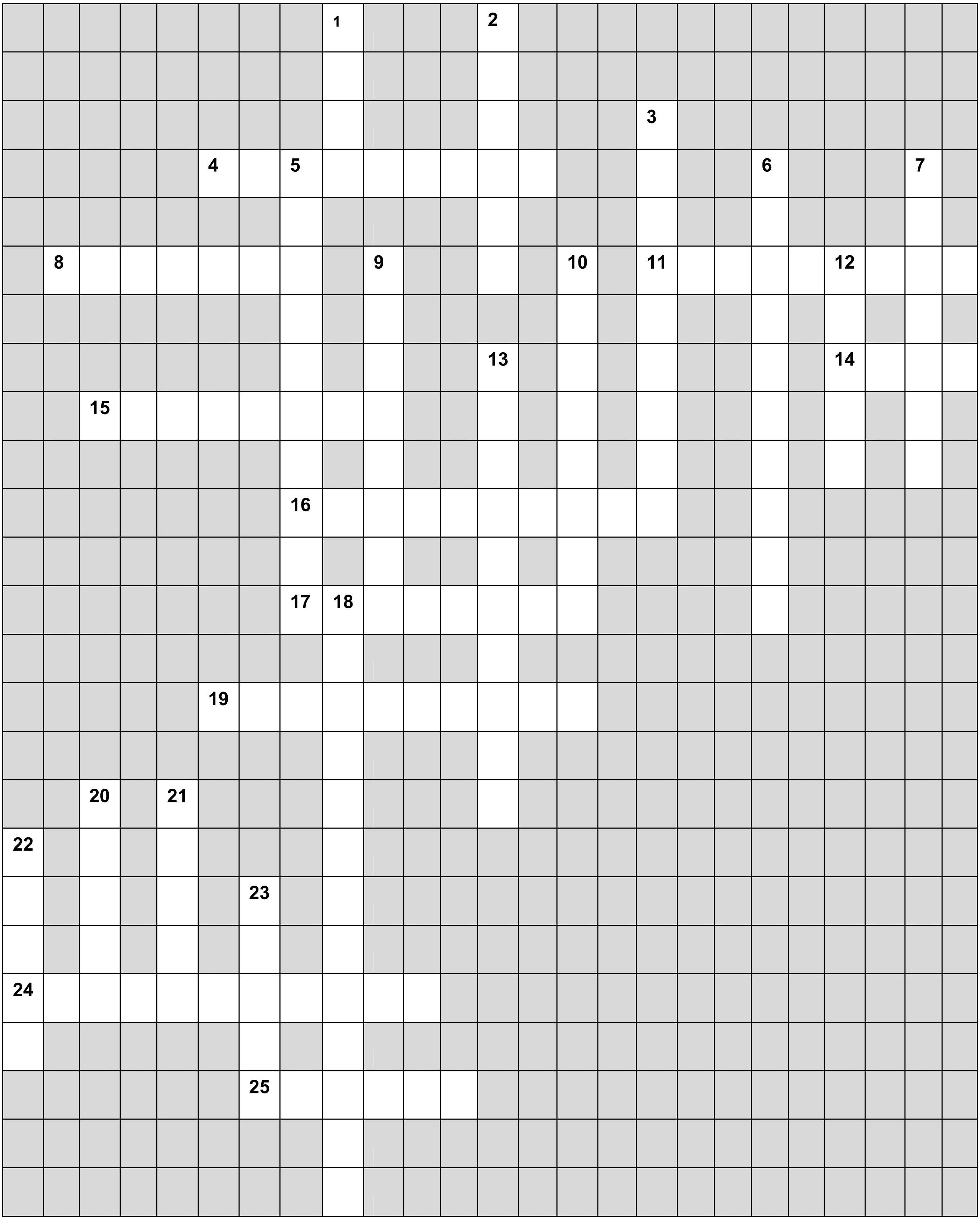
Activity: Crossword

Solve the crossword using the clues which are all related to Electrical and Electronic engineering.

Clues

Across	Down
4 Can be ferrous, non ferrous or plastic (9)	**1** Circuit protective device (4)
8 The unit is the volt (7)	**2** Wires (6)
11 A one way switch is one (9)	**3** Component measured in Farad (9)
14 Opposite to closed (4)	**5** Temperature to resistance (10)
15 Protection using CPCs (8)	**6** ET call rice (anag) (10)
16 Electronic device with three legs (10)	**7** Measured in Ampere (7)
17 Colour coded component (8)	**9** Drawings (8)
19 Electronic parts (10)	**10** Coil (8)
24 Digital or analogue (11)	**12** Not long (5)
25 Used to turn circuits on – off (6)	**13** Limits current in a circuit (10)
	18 Skills that employers value (13)
	20 Current flows one way in this (5)
	21 Not dark
	22 555
	23 Lotos (anag) (5)

Activity: Crossword



								1 F				2 C												
								U				A												
								S				B				3 C								
					4 M	A	5 T	E	R	I	A	L	S			A			6 E				7 C	
							H					E				P			L				U	
	8 V	O	L	T	A	G	E		9 D			S		10 I		11 A	C	C	E	S	12 S	O	R	Y
							R		I					N		C			C		H		R	
							M		A			13 R		D		I			T		14 O	P	E	N
		15 E	A	R	T	H	I	N	G			E		U		T			R		R		N	
							S		R			S		C		O			I		T		T	
							16 T	R	A	N	S	I	S	T	O	R			C					
							O		M			S		O					A					
							17 R	18 E	S	I	S	T	O	R					L					
								M				A												
					19 C	O	M	P	O	N	E	N	T	S										
								L				C												
		20 D		21 L				O				E												
22 T		I		I				Y																
I		O		G		23 T		A																
M		D		H		O		B																
24 E	L	E	C	T	R	O	N	I	C	S														
R						L		L																
						25 S	W	I	T	C	H													
								T																
								Y																

Activity: Word - count

How many words of 3 or more letters can you make from the word:

Employability

Activity Answers

Word - count

Score 40 to 60 - Very Good

Score over 60 - Excellent

Workshop Task Sheets

Lesson 1 – Activity

Tool Identification

Your tutor will show you a selection of numbered tools – fill in the table with what you think they are called and what they do.

Tool	Tool Name	Tool Purpose
Tool 1		
Tool 2		
Tool 3		
Tool 4		
Tool 5		
Tool 6		
Tool 7		
Tool 8		

Remember Employability

Are you attending regularly?

Lesson 2 – Activity

Cut and Terminate Cable

In this activity you will measure, mark, cut and terminate 4 lengths of electrical cable.

The termination is to be crimped with ring tags.

Checklist:

Correct procedures must be followed:

- use safe working practices, observe health and safety regulations and remember employability tips
- use the correct measurement units from the stated work instructions (below)
- use the correct marking, cutting and termination tools
- use the tools solely for the intended purpose
- check the cable against the work instructions
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity.

Lesson 2 - Activity

Cut and terminate cable – Work instructions

1. Cut 4 pieces of multi-strand cable 250mm long.

2. From each end strip the insulation for about 6 - 8mm.

   Handy Hint
   It helps the crimp process if after the insulation has been stripped off the cable the copper strands are twisted clockwise to tighten them together.

3. Fit the crimp terminal over the exposed copper conductor:

   Handy Hint
   Sometimes it's easier to use the crimp tool to hold the crimp in place and then insert the exposed copper conductor into the crimp.

4. Use the crimping tool to compress the crimp onto the copper conductor.

5. Crimp at the insulation end to help to support the cable.

Handy Hint
You should be able to see some of the copper conductor at the ring side of the crimp but not at the insulation side.

Remember Employability

Are you on time?

How long do you take for breaks?

1, 2, 3, 6, 8, 9

Lesson 3 – Activity

Cut and Terminate Cable to Accessories

In this activity you will measure, mark, cut and terminate twin and earth cable to the following:

1. Lamp Holder (Batten or Ceiling Rose)

2. One Way Switch

Checklist:

Correct procedures must be followed:

- use safe working practices, observe health and safety regulations and remember employability tips
- use the correct measurement units from the stated work instructions (below)
- use the correct marking, cutting and termination tools
- use the tools solely for the intended purpose
- check the cable against the work instructions
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity.

Lesson 3 - Activity

Cut and Terminate Cable to Accessories – Work instructions

1. Cut 3 pieces of twin & earth (T & E) cable 500mm long.

2. At one end of the T & E strip the outer insulation for about 40 mm, strip the inner insulation for about 6 - 8mm.

Handy Hint
The amount the inner and outer insulation should be stripped may change depending on the accessory to be connected.

3. Connect the first T & E cable to lamp holder.

Handy Hint
Do not over-tighten the connector screws.

Handy Hint
Remember to add the earth sleeving to the earth wire and connect to the earth terminal.

4. Connect the second T & E to the one way switch.

Handy Hint
You should not be able to see any of the copper conductor.

Handy Hint
Remember to add the earth sleeving to the earth wire and connect to the earth terminal.

5. Connect the third T & E to a Consumer Unit

Handy Hint
Strip the outer insulation for about 150 mm, this allows greater flexibility for connection within the consumer unit.

6. Mount the accessories on a suitable board.

Handy Hint
Remember to use a bradawl in preparation for screws.

Handy Hint
Do not over-tighten the mounting screws – you could damage the accessory.

Remember Employability

Are you working in a safe manner?

Lesson 4 – Activity

Construct and test a one way switched lighting circuit

In this activity you will construct a one way switched circuit and complete continuity tests.

Checklist:

Correct procedures must be followed:

- use safe working practices, observe health and safety regulations and remember employability tips
- use the correct measurement units from the stated work instructions (below)
- use the correct marking, cutting and termination tools
- use the tools solely for the intended purpose
- check the cable against the work instructions
- clean and store tools correctly
- clean the work area on completion
- record how well you completed the activity.

Remember Employability

Did you have a positive attitude to learning?

Lesson 4 - Activity

Construct and test a one way switched lighting circuit – Work instructions

1. Measure and mark the board as shown in the board **layout diagram**.

2. Fit the accessory bases on a suitable board.

Handy Hint
Remember to open the cable entry point on each accessory base.

3. Run the T & E cable to/from each accessory.

Handy Hint
At each accessory leave a little extra cable.

4. Connect the T & E to the one way switch.

Handy Hint
The brown conductor is termed the live (also called phase) and the blue is now called the 'switch live' and should be marked by a piece of brown sleeving at both ends.

Handy Hint
Remember to add the earth sleeving to the earth wire and connect to the earth terminal or if no earth terminal, sleeve the earth and tuck out of the way. This is because in future a metal clad switch may be fitted and this would require an earth connection.

5. Connect the two T & E cables at/to the lamp holder.

Handy Hint
At the lamp holder connect as follows:
The two brown conductors together in the centre terminals
The two earths at the earth terminal
The two blue conductors at the blue (neutral) terminal, this will have the blue conductor of the lamp holder.
The switch live (blue with a brown sleeve) at the lamp 'live which will be the brown conductor of the lamp holder.
Do not over tighten the connector screws.

6. Complete continuity tests.

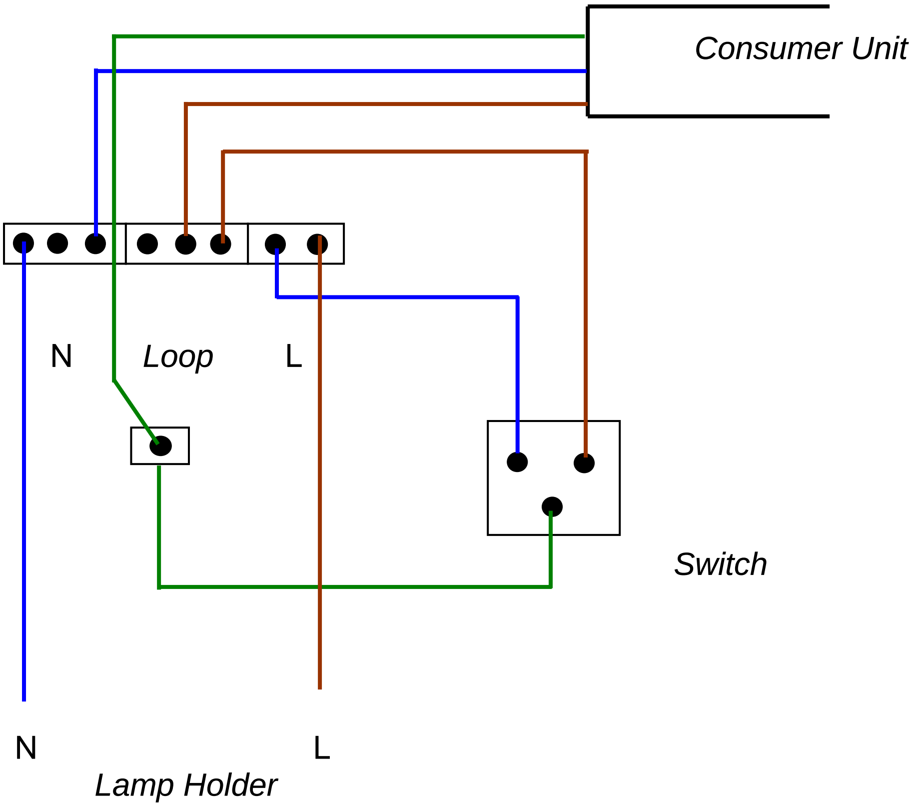
7. Complete functionality test.

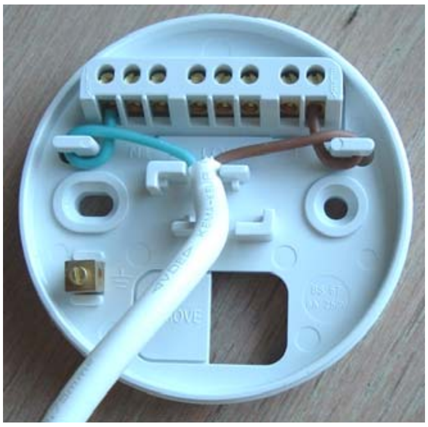
Remember Employability

Did you clean and store tools correctly?

Lesson 4 - Activity

Wiring Diagram – Lamp Holder





Remember the **blue** conductor from the switch to the lamp holder has **brown** sleeving at both ends to show that it is the 'switch live'.

Lesson 4 - Activity

Continuity Tests - One Way Lighting Circuit

Continuity Tester - ______________________________

One Way Lighting Circuit

Live (Phase) - Test	**Accept**	**Reject**
Main Intake Live to:		
Lamp holder (Switch On)		
Lamp holder (Switch Off		
Neutral conductor		
Earth conductor		
Neutral - Test		
Main Intake Neutral to:		
Lamp holder		
Live conductor		
Earth conductor		
Earth - Test		
Main Intake Earth to:		
Earth at lamp holder		
Earth at switch		
Live conductor		
Neutral conductor		

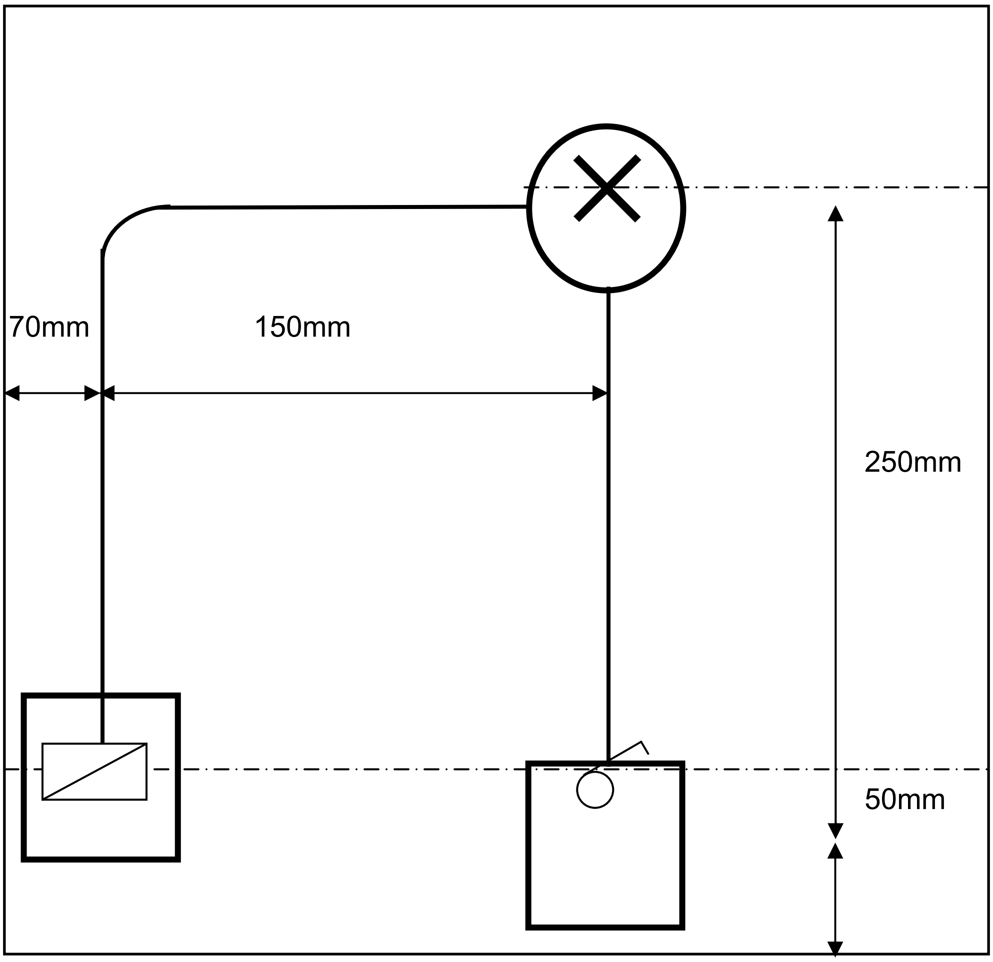
Remember Employability

Did you manage to follow the diagrams?

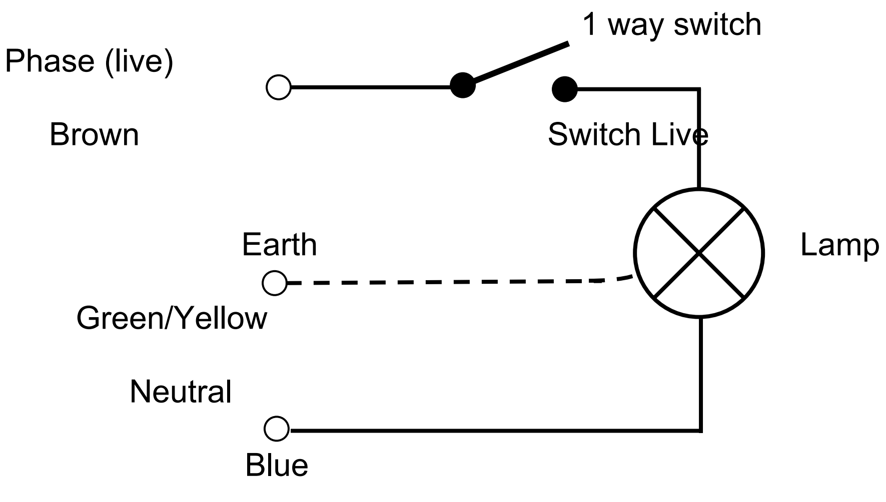
Lesson 4 - Activity

Construct and test a one way switched lighting circuit – Work instructions

Board Layout - One Way Lighting Circuit



Circuit Diagram - One way Lighting Circuit



Lesson 5 – Activity

Electronic Component Identification

Your tutor will show you a selection of numbered electronic components – fill in the table with what you think they are called, their circuit symbol and if appropriate the component value.

Component	Component Name	Component Symbol	Component Value
Component 1			
Component 2			
Component 3			
Component 4			
Component 5			
Component 6			
Component 7			
Component 8			

Remember Employability

Do you have a positive attitude to learning?

Ask questions – if you are not sure of something

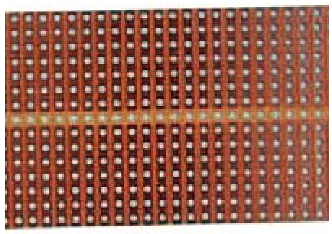
Lesson 6 – Activity

Soldering - Wire Termination

Your tutor will give you various types of cable:

- single core
- multi core
- screened
- co-axial
- ribbon

terminate to stripboard (veroboard) or similar by:



1. Cut the various cables to length (200mm)

2. Strip the insulation (10mm)

3. Tin the copper conductor

4. Trim the length of tinned end to 4mm – 6mm

5. Solder the cable to the board, trim if required.

Handy Hint

Remember to constantly clean the soldering iron.

Remember Employability

Did you source and use tools in a correct and safe manner?

Lesson 7 – Activity

Solder - Desolder - Termination of Components

Your tutor will give you various electronic components from the following:

- switches
- lamp holders
- resistors
- capacitors
- inductors
- diodes
- transistors
- audio/visual devices

to terminate to stripboard (veroboard) by soldering.

Solder

1. Bend components to shape

2. Secure to board

3. Solder components to the board

4. Desolder components from the board.

Handy Hint
Remember some component legs may require cleaning or tinning

Handy Hint
Remember to constantly clean the soldering iron.

Desolder

Using the solder sucker (or similar) remove 3, or more, components from the board.

Remember Employability

Did you use tools solely for the purpose for which they were designed?

Lesson 8 – Activity

Construct and test a simple timing circuit – Work instructions

This circuit can be constructed using any of the following:

- Printed Circuit Board (PCB)
- Proto-board
- Vero-board
- Strip-board
- Bread-board
-

or any other similar board that will allow circuit construction.

1. List components required

2. Check components against board size

3. Bend components to size

4. Secure components to board

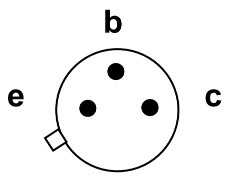
5. Solder components to board

6. Complete circuit continuity tests

Complete circuit function test

Handy Hint

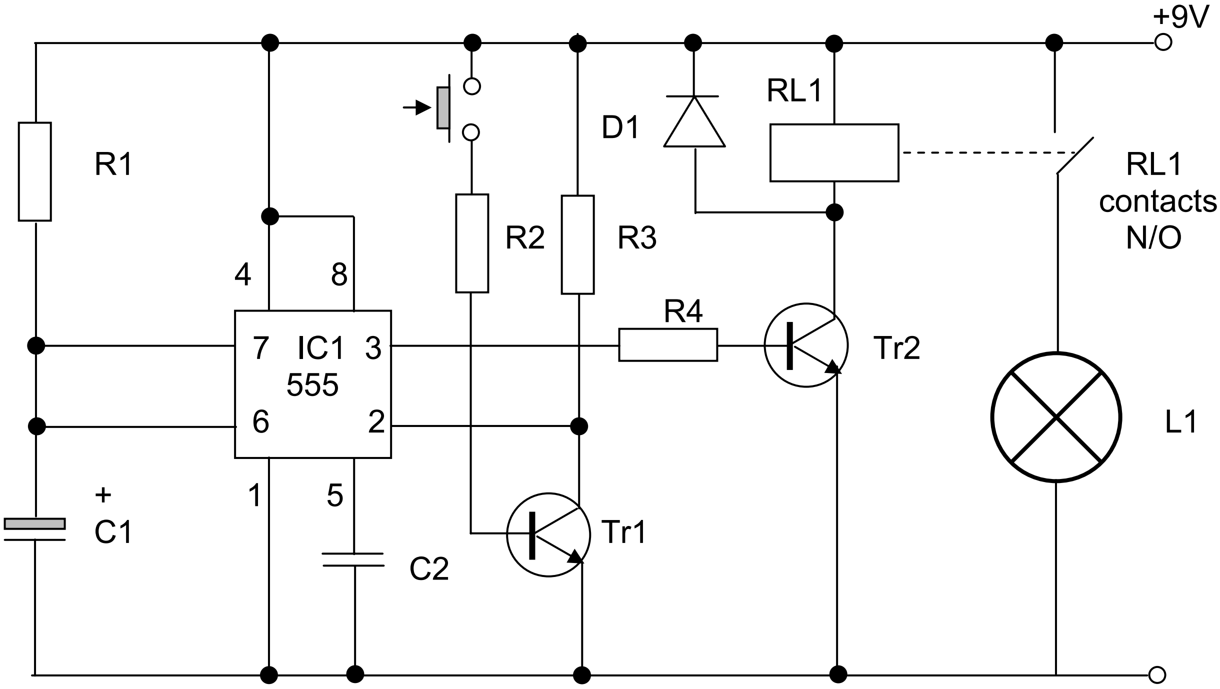
Remember the legs of the transistor fit to the board in the opposite way from that identified, so double check the transistor leg connections.



Handy Hint

There are many computer simulation and construction packages which could assist with the circuit construction and component layout.

Lesson 8 – Activity - Timing Circuit



R1	470kΩ	C1	10μF, 16V electrolytic
R2	1kΩ	C2	0.01μF ceramic
R3	10kΩ	Tr1	BC109
R4	1kΩ	Tr2	BC109
RL1	Relay 9V 1A		
L1	Lamp Holder and Bulb		
S1	momentary on-switch		

Timer Circuit:
The 555 timer is wired to have one stable state (monostable multivibrator). A pulse is applied by the switch S1, this causes the circuit to switch to the other state which is timed at about 6 seconds. This other state switches on the transistor Tr2 and this energises the relay RL1 for the same 6 seconds.

In technical terms the operation of S1 causes:
- Tr1 to conduct
- Pin 2 of the 555 goes low.
- the time set by R1 * C1
- Pin 3 goes high
- Tr2 to conduct
- Relay energises for about 6 seconds.

The lamp can be replaced by an audio device and the timing can be altered by changing either R1 or C1 or both.

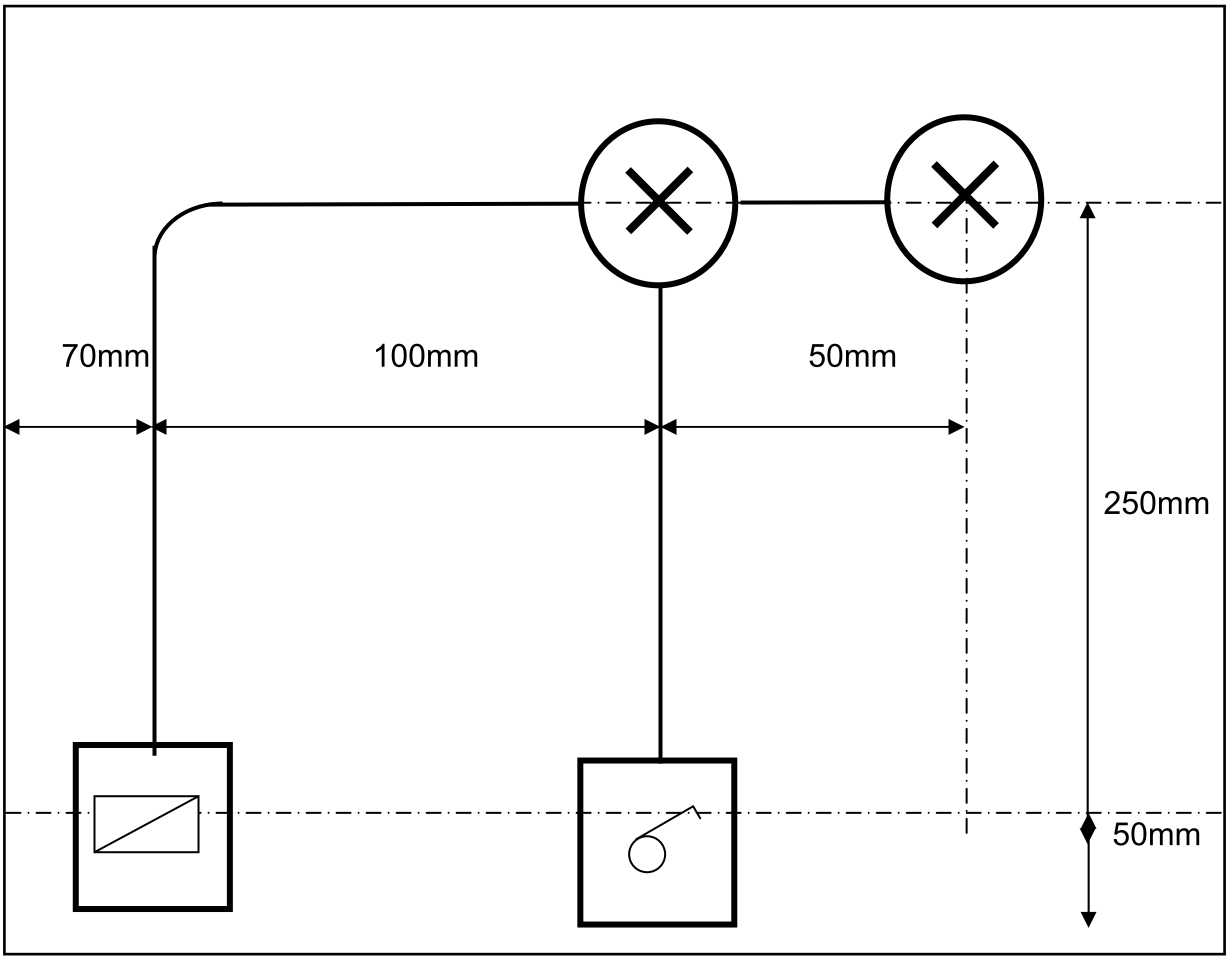
Remember Employability

Did you remember Health and Safety at all times?

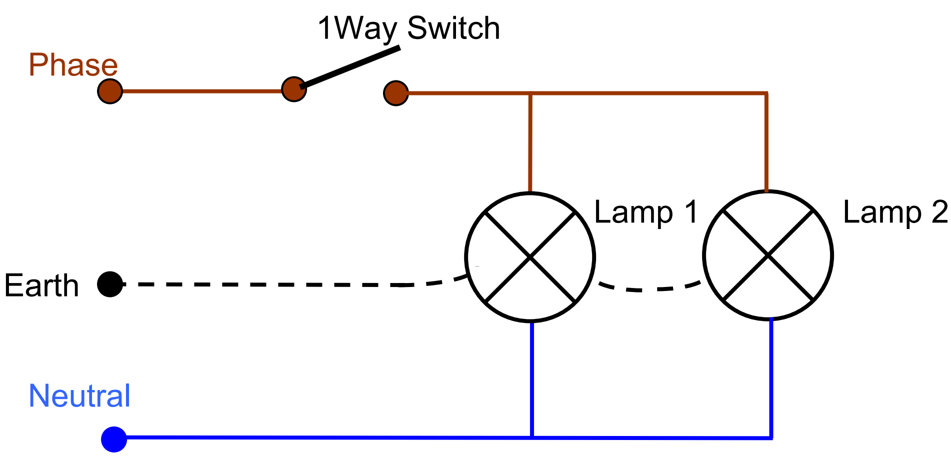
Additional Activity 1 - Electrical

Construct and test a One Way Lighting Circuit With Additional Lamp – Work instructions

Board Layout - One Way Lighting Circuit with Additional Lamp



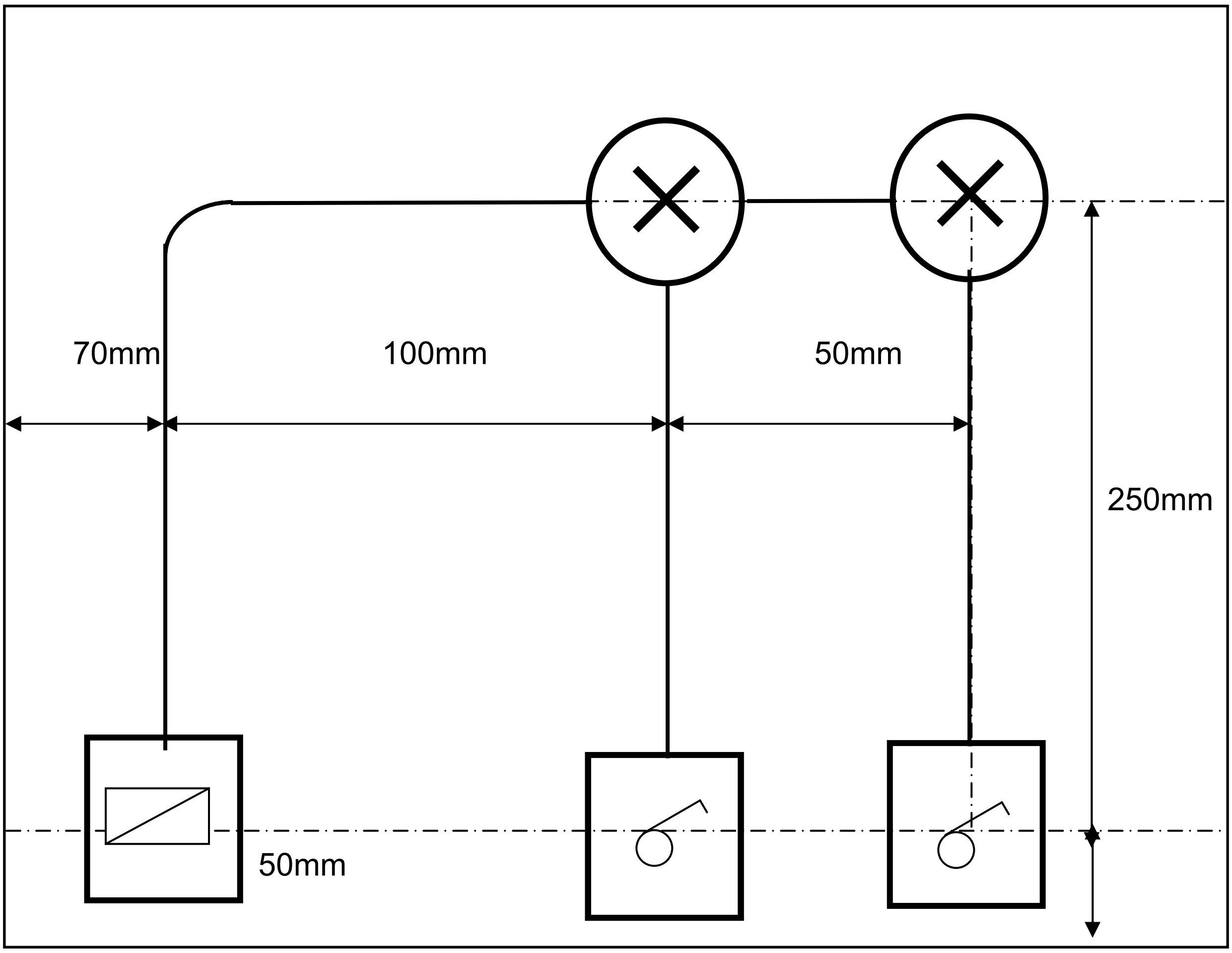
Circuit Diagram - One Way Lighting Circuit with Additional Lamp



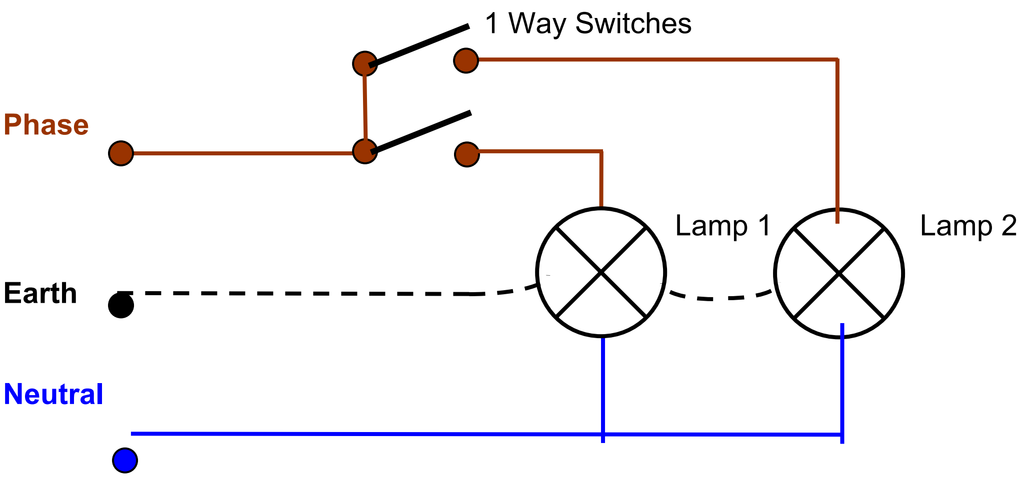
Additional Activity 2 - Electrical

Construct and test a Circuit with Two- One Way Switches - Work instructions

Board Layout: Two - One Way Lighting Circuits



Circuit Diagram: Two - One Way Lighting Circuits

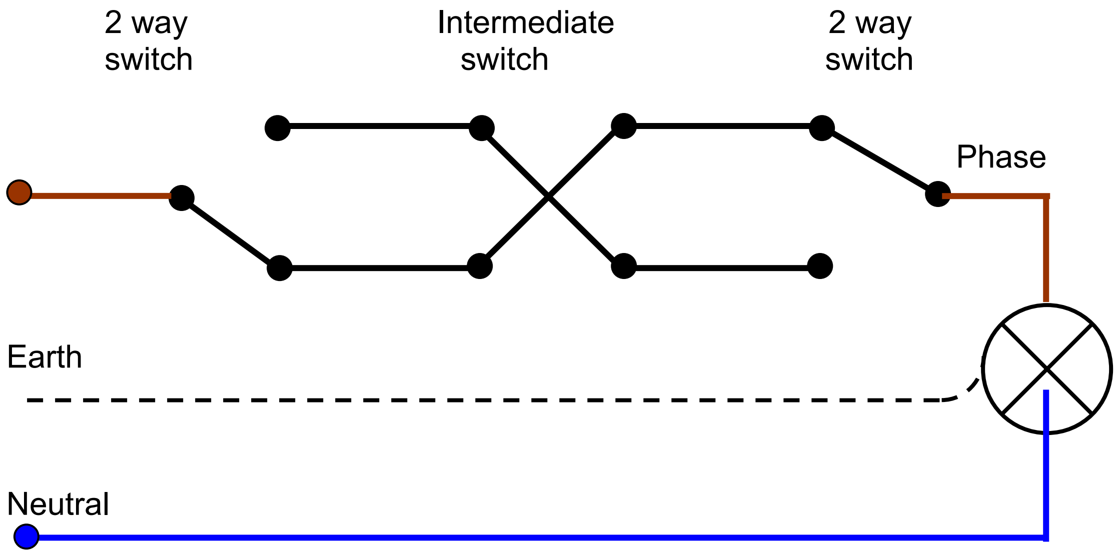


Additional Activity 3 - Electrical

Construct and test a Intermediate Lighting Circuit with Two-One Way Switches - Work instructions

Board Layout – Design a suitable layout for this circuit using the other layout boards for guidance.

Circuit Diagram



Additional Activity 4 - Electronic

Construct and test a simple Amplifier Circuit – Work instructions

This circuit can be constructed using any of the following:

- Printed Circuit Board (PCB).
- Proto-board
- Vero-board
- Strip-board
- Bread-board
-

or any other similar board that will allow circuit construction.

1. List components required

2. Check components against board size

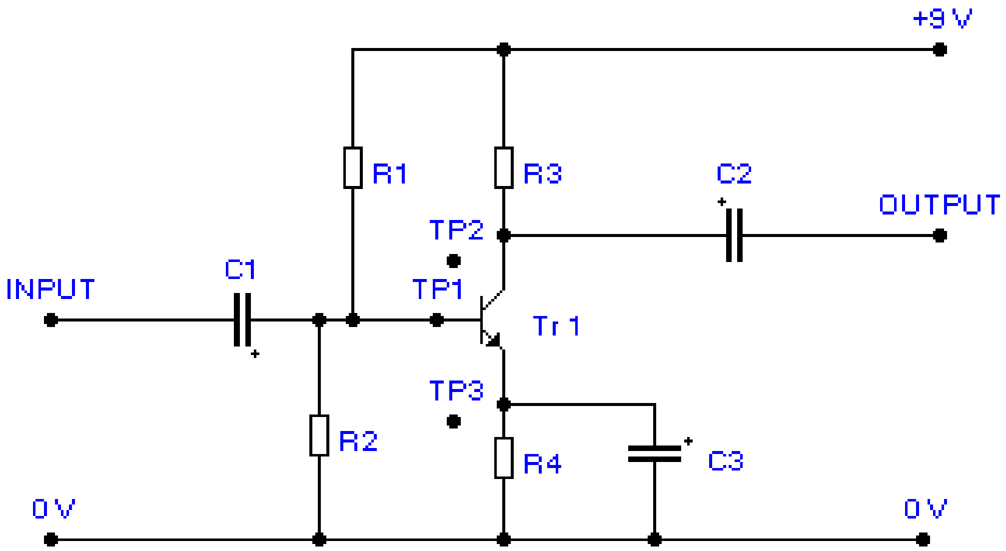
3. Bend components to size

4. Secure components to board

5. Solder components to board

6. Complete circuit continuity/function tests

Circuit Diagram



Component List:-	R1	47KΩ	C1	10μF
	R2	10KΩ	C2	10μF
	R3	5.6KΩ	C3	47μF
	R4	1KΩ	Tr1	BC109/108/107

Additional Activity 5 - Electronic

Construct and test a simple Continuity Tester – Work instructions

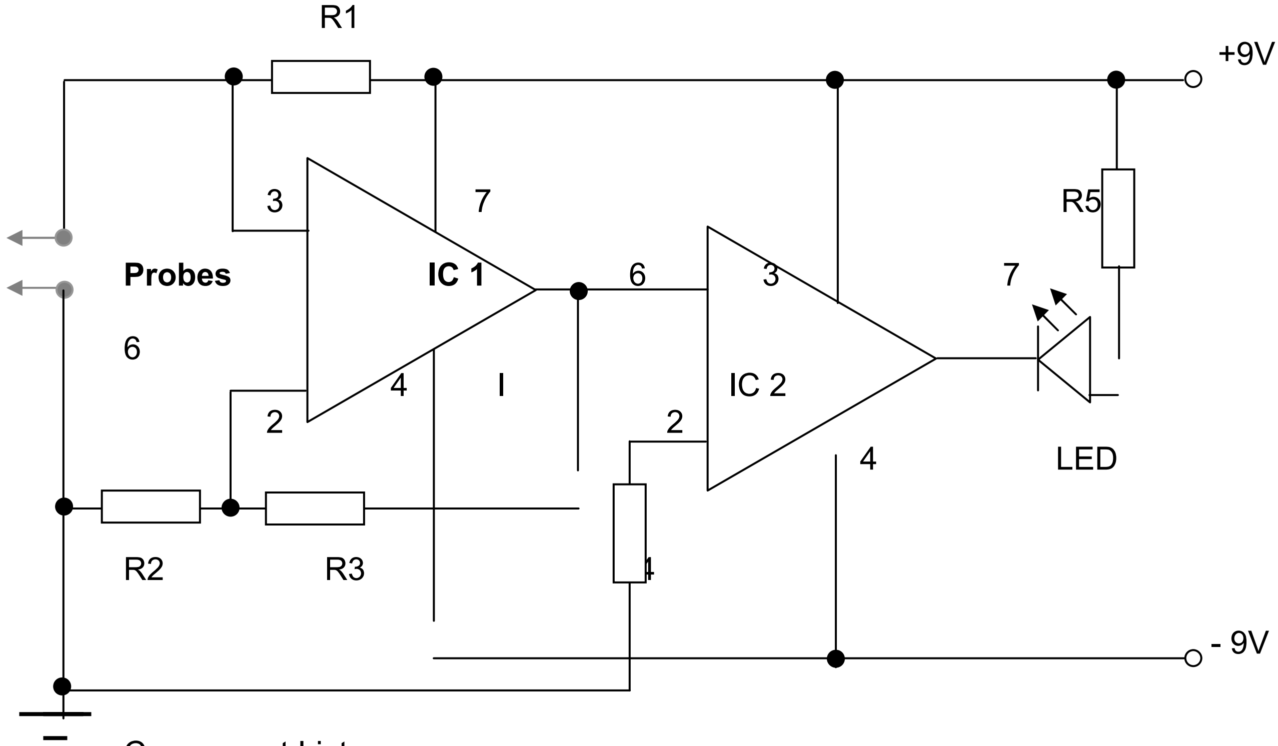
This circuit can be constructed using any of the following:

- Printed Circuit Board (PCB)
- Proto-board
- Vero-board
- Strip-board
- Bread-board
-

or any other similar board that will allow circuit construction.

1. List components required
2. Check components against board size
3. Bend components to size
4. Secure components to board
5. Solder components to board
6. Complete circuit continuity/function tests

Circuit Diagram



Component List:

R1	100kΩ	LED	Colour your choice
R2	12kΩ	IC 1 & 2	LM 741
R3	1k2Ω		
R4	120kΩ		
R5	470Ω		

Practical Activity Checklist

Candidate Name	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Activity 8

Unit Questionnaire

This questionnaire is designed to help your lecturer find out how you feel about this unit.

You don't need to put your name on this questionnaire.

Instructions: Please complete this form by placing ✓ in the most appropriate box.

Unit Title:				
Lecturer's Name:			**Date:**	
		Strongly Agree	**Agree**	**Disagree**
1	The induction to this unit was helpful.			
2	My teacher/lecturer helped me through this unit.			
3	The resources and equipment were suitable.			
4	All Health and Safety information and practices were effective.			
5	My teacher/lecturer prepared me well for assessments.			
6	I was given constructive feedback.			
7	I was kept informed of my progress regularly.			
8	I enjoyed this subject.			

Please add any comments you feel are important to make this subject better:

Thank you for completing this questionnaire.

Glossary of Terms

Term	Meaning
Amplify	amplify is applied to signals and means to make bigger
Analogue	when applied to electronics means continually changing
Attenuate	Is applied to signals and means to make smaller
Bayonet cap	is a type of connection for an ordinary light bulb that is connected by a push-up and quarter turn
Block diagram	a block diagram shows the circuit or system split into simple blocks that are labelled with the function of the block
Bolster	a name for a floorboard chisel
Cable	a conductor with an insulated sheath
Capacitor	a component that is capable of storing energy in the form of an electrostatic field and has many applications in electrical and electronic circuits
Circuit	a closed loop that has a voltage source and a load, with the source and load connected by conductors
Circuit diagrams	shows how the circuit operates by showing the cables, connections and components in schematic form
Consumer unit	the main intake of a domestic supply is commonly known as a consumer unit
Continuity test	a continuity test checks the circuit, or part of a circuit is a complete loop
CPC	the circuit protective conductor is the earth and provides an easy path for fault currents
Crimp	A method of termination for a conductor that involves clamping a terminal on the conductor
Current	current flow is the movement of electrons but in essence is the transfer of energy
Data transmission	the sending of information which may be graphics, sound or speech
Desolder	is the opposite of soldering and in this case heat is applied to separate soldered joints
Digital	when applied to electronics means discrete steps
Diode	component that allows current to pass in one direction but not the other direction

Dry joint	is a bad soldered joint
Edison screw	is a type of connection for an ordinary light bulb that screws into the lamp holder
Electrical conductivity	is the ability of a material to let a current flow
Electrical insulation	is the ability of a material to resist a current flow.
Ferrous	ferrous metals contain iron, meaning this material will rust
Flux	flux is used in soldering to clean the joint
Fuse	a safety device that breaks the circuit if the current becomes too large; a protective device that comes in a cartridge form that breaks the circuit when a large current flows; the fuse is not as easy as a MCB to reset
Helping hands	an aid to soldering that holds the piece to be soldered securely in place
IEE wiring regulations	are the Institute of Electrical Engineer's regulations, they are not rules and as such are only recommended practice to prevent fire or electric shock
Inductor	a component that is capable of storing energy in the form of a magnetic field and has many applications in electrical and electronic circuits
Insulated	material that does not allow current flow and is used to stop copper conductors from touching
Layout diagram	shows the physical position of each component or accessory
Lighting circuit	a circuit with switches and lights
Logic	a system that takes what is known to be true and predicts an outcome; like the Vulcan in Star Trek 'it is logical'
Logic gate	a digital circuit that follows simple logic rules
Mains voltage	is the domestic voltage supply which is 230V
MCB	a miniature circuit breaker that is rated in Ampere and trips like an automatic switch but can be reset very easily
Non-ferrous	non-ferrous materials do not contain iron and will not rust or corrode, copper is non ferrous
Non-metallic	non metallic materials contain no metals and are generally resistant to corrosion; this term applies to plastic

Ohm's law	Ohm's law states that, in an electrical circuit the current (I) that flows is directly proportional to the voltage applied to the circuit
Open circuit	this is when the circuit is broken by a fuse, RCD, switch, MCB or by a circuit fault
PVC	(Polyvinyl chloride) is the most widely used, being a clean, easy to handle material suitable for either fixed or flexing installations. It is available in various grades to suit differing environmental conditions.
Plug top	the plug top is widely used to connect a range of appliances to the supply
Portable electrical equipment	electrical equipment that can be carried, without too much effort from one location to another
Power circuit	a circuit with sockets
RCD	a residual current device that compares the current in the live against the current in the neutral and trips when there is a small difference
Resin core solder	this type of solder has the flux as a core and as the solder is used the flux is dispensed automatically
Resistance	is the opposition to the transfer of energy
Resistor	a component that opposes the flow of current
Schematic	the term for an electrical diagram that uses symbols that is a pictorial representation of an electrical circuit
Short circuit	is a fault condition when a live is touching a neutral conductor or an exposed metal part. A short circuit causes a large current to flow.
Single phase	is the type of domestic supply
Soldering	a thermal joining method of electrical connection
Tin	is the term for covering (tinning) a copper conductor with a thin layer of solder
Transistor	a component that is widely used in electronic circuits to both switch and amplify
Voltage	is the pressure that makes current flow
Wattage	is the measure of energy used in a certain time
Wiring diagram	shows the route the cabling or wiring takes and sometimes gives the connection details

These boxes are for you to add any other terms that you use during the course:
