FACILITATOR GUIDE

BASIC PRINCIPLES OF COMPUTER PROGRAMMING AND COMPUTER LITERACY

Godwin Dzvapatsva

NATIONAL CERTIFICATE VOCATIONAL

ISBN 978-0-63911-105-6

First edition 2022

FutureManagers

SIYAFUNDA • SIYAKHULA

Published by
Future Managers (Pty) Ltd
PO Box 13194, Mowbray, 7705
Tel (021) 462 3572
Fax (021) 462 3681
E-mail: info@futuremanagers.com
Website: www.futuremanagers.com

Contents

Icon key

Whenever you see the following ICONS in this textbook, this is what they mean:

INDIVIDUAL ACTIVITY
Indicates an activity to be done alone.

PAIR ACTIVITY
Indicates an activity to be done in pairs.

GROUP ACTIVITY
Indicates an activity to be done in groups.

INVESTIGATION
Indicates an activity that requires investigation.

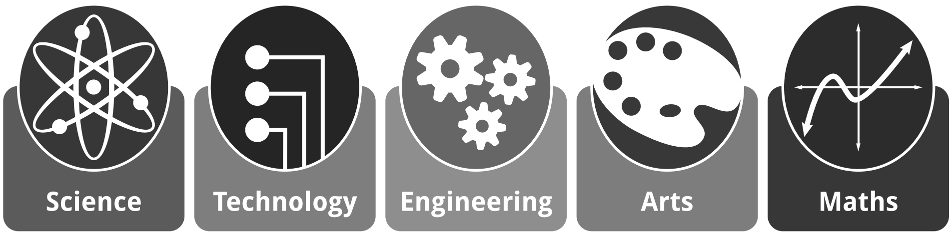
TASK
Practise this skill in the simulated environment or practicum room.

SUMMATIVE ASSESSMENT
This is the activity that you will need to complete and tear out to be handed in to your lecturer as part of your assessment mark.

1. Overview of the subject

With the advent of the Fourth Industrial Revolution (4IR), new mechanisms and approaches are required to enable students and those already settled in existing career paths to upgrade their skillsets. This notion is particularly important in the computer science and engineering disciplines, as the educational sector needs to keep up with the pace at which new technologies are developed and deployed.

The driving forces for the market and the world of the future are rooted in competitiveness. Successes and failures depend on which technologies are applied and how they are applied, rather than on the technologies themselves. Another contributing factor is the speed at which the knowledge of the technology changes (Fernandez, et al. 2015).



1.1 Main subject aim

Electronics and Digital Concepts for Robotics (EDCR) aims to equip students with functional 4IR technology capabilities through the transfer of necessary trade-specific skills, knowledge, values and attitudes (SKVAs).

1.2 Electronics and Digital Concepts for Robotics Level 2

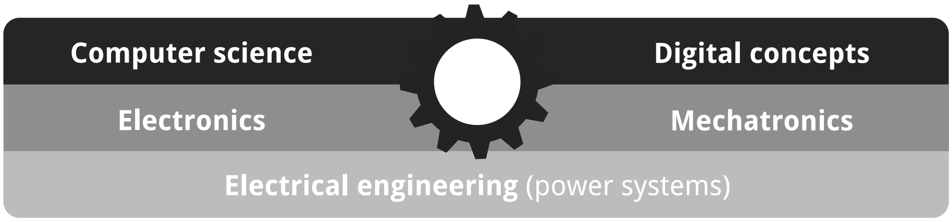
EDCR Level 2 covers the basics of electronics and is designed to introduce the field of learning. The assumption is made that the student has no previous electronics background. The subject aims to transfer the necessary trade-specific SKVAs to students.

EDCR focuses on the understanding and application of electrical and electronic principles. The four main areas of specialisation are the following:

- Electronics
- Electrical engineering (power systems)
- Digital concepts
- Mechatronics
- Computer science.

The term *mechatronics* describes the integration of electronic engineering, electrical engineering, computer technology and control engineering with mechanical engineering. This process forms a crucial part of the design, manufacturing and maintenance of a wide range of engineering products and processes. Consequently, there is a need for engineers and technicians to adopt an interdisciplinary and integrated approach, involving skills and knowledge that are not confined to a single subject area. They should be able to operate and communicate across a range of engineering disciplines.

In the following section, the respective areas of specialisation are described and placed within the intended context.



Electronics

As a component of EDCR, electronics introduces analogue electronics using mainly light current applications. In Level 2, students will be introduced to the principles of electricity and current flow.

Electrical engineering

Electrical engineering (power systems) refers to various applications of electricity using heavy current from the mains supply. In Level 2, the student is introduced to direct current (DC) and other practical applications.

Mechatronics

As mentioned earlier, mechatronics is the integration of electronics, electrical engineering, computer technology and control engineering with mechanical engineering. A wide range of engineering products and processes relies on this process for their design, manufacturing and maintenance. It is therefore essential for engineers and technicians to apply an interdisciplinary and integrated approach, encompassing skills and knowledge that are not confined to a single field.

Digital concepts

This aspect of the curriculum has strong links to computers, programmable integrated circuits, Boolean algebra, microcontrollers, system control, processors and programming. In Level 2, the student is introduced to the principles of electricity and electronics, similar to an electronics student.

Computer science

The link between computer science and EDCR as a whole has already been emphasised with reference to the digital concepts.

Additional advantages

EDCR for Robotics has additional pedagogical and developmental advantages. These are summarised below.

- **Creative thinking**
  EDCR incorporates creativity, imagination and elements of fun. This promotes the allure of the subject and motivates students to further explore and learn.
- **Engagement**
  Practical learning enable students to learn new fundamental skills while promoting concentration and developing psychomotor abilities.

- **Preparedness**
  Technological advancements necessitate new opportunities to prepare students for the future. This aspect basically relates to the development of skills that will prepare students for the rapidly changing world. It stimulates and develops students' engineering intuition and accentuates meaningful problem-based learning.
- **Computational thinking**
  Computational thinking is a problem-solving process that encourages students to develop sets of skills that include decomposition, pattern recognition, abstraction and algorithm design.
- **Evaluation**
  This entails that the student engages in critical self-reflection and assessment in order to determine the degree to which the artefact or design meets the set criteria. It allows the student the opportunity to reflect on areas that require possible further attention and practice.
- **Communication**
  This skill is essential, as it allows students the opportunity to share ideas, both verbally and in other means, and stimulates collaboration and group-directed learning.
- **Perseverance**
  Creating and designing electronic-based tools and artefacts are a challenge and present students with the opportunity to hone and develop a never-give-up attitude. It also imparts determination, which is vital in any technological, design and scientific endeavour.
- **Collaboration**
  EDCR as a subject incorporates a range of skills and indorses an environment of learning among students with different talent sets. Using each student's strengths could promote an ethos of collaboration and harness goal-directed development or teamwork.
- **Abstract thinking**
  This is the ability to think about aspects and things that are currently not present. In the field of robotics, it is related to symbolic thinking and the realisation of ideas.
- **Programming**
  Programming is a medium, a literacy or a form of communication and expression. It presents the robotics student with a means to explore and practically experience the aspects encapsulated in computation. Programming involves coding and students need to design and present step-wise solutions and transform the abstract into the symbolic.
- **Fun**
  Students engaging in robotics as a subject are stimulated due to the fun nature of the subject. The subject can present positive user experiences and encouragement.

2. Development of learning and teaching support materials and teaching strategy

The developers of any learning and teaching support material (LTSM) should consider the fact that a curriculum statement and syllabus, such as the one provided here, is made up of various contextual topics and subject outcomes and therefore should not be used as a table of contents for writing textbooks. The topics and subsequent numbering of subject and learning outcomes also do not necessarily indicate the sequence in which material should be presented.

Knowledgeable subject experts and LTSM developers will logically group different subject and learning outcomes and will present these in an educationally sound, coherent and sequenced manner to provide students with an authentic integrated learning experience. Core competencies and skills should be presented, covering both the theoretical and the practical aspects of the subject.

Lecturers should design their own work schedules (or use/adapt the work schedule provided in the Facilitator's Guide) to appropriately group and sequence content, considering comfortable pacing of the curriculum matter.

The subject outcomes (SOs) and learning outcomes (LOs) presented should not be seen as stand-alone topics, but relevant SOs and LOs or content should be presented in an integrated manner.

Integration of curriculum content in the lesson presentation should flow naturally according to the nature, links and overlapping of the content. For example, some content from one SO and LO may strengthen and underpin the content of another. This approach should be applied throughout the three-year curriculum.

It is important that the specific technologies in the teaching plans are revised at regular intervals to phase out old technologies and include new technologies.

3. Main topical areas

The table below illustrates the main topic areas of the EDCR subject.

ELECTRONICS AND DIGITAL CONCEPTS FOR ROBOTICS TOPICAL OVERVIEW		
LEVEL 2	**LEVEL 3**	**LEVEL 4**
• SI units and introduction to atomic theory • Electrical supply systems, Ohm's law, Joule's law and related theoretical aspects • Basic electronic components and semiconductors • Electrical components, symbols, circuit drawings, prototyping and design • Electronic tools and equipment • Digital systems and principles • Workshop ethics, safe use of equipment and operational health and safety	• Magnetism, electromagnetic circuits and related concepts • Electrical supply systems, transformers, DC machines, series-parallel networked circuits • Electronic components and semiconductors • Electrical components, symbols, circuit drawings, prototyping and design • Electronic tools and equipment • Digital systems, PLCs and principles • Functions • Strings • Data structures	• Alternating current theory • Electrical supply systems, DC networks • Electronic components and semiconductors • Electrical components, symbols, circuit drawings, prototyping and design • Digital systems and principles

4. Teaching time and offering type

The instructional offering is presented full-time over two semesters **spanning 24 weeks (not including assessment)**.

This is equivalent to the following:

- 24 × (two × double periods of ± 1 hour 50 minutes each) + 1 (single period of ± 50 minutes)
- 56 hours (± 4,5 hours per week) of which:
  - 36 hours are instructor-led contact hours (which also include practical sessions); and
  - 18 hours are instructor-led contact hours dedicated *to practical tutorials* (on PCs).
- In addition, *a further 10 hours per term* (i.e. ± 1,5 hours per week) are required for students to practice on their own to reinforce and master practical concepts and skills. (This should be accommodated in open labs provided by the college.)

5. Resources

5.1 Physical resources

Well-equipped classrooms and workshops are essential for this practical-orientated subject. If possible, using the facilities of employers in the electrical and electronics field for training is preferred.

5.2 Human resources

Lecturing staff must have appropriate electrical and or electronic engineering-related qualifications and should possess the necessary knowledge, skills and reflective approach. This to ensure that students' learning is kept up to date with the latest technologies and changing trends in their specialist field.

Continuous staff development with exposure to an industrial environment is necessary to acquire new skills and update existing skills where new technologies have been introduced. Lecturers are required to spend a structured and routine period annually in an industrial environment for these purposes.

EDCR requires a trained subject specialist. It is preferred that the EDCR lecturer is an artisan/technician/technical teacher in an electrical-/electronic-/digital-related area. Industry-related experience and workshop management skills are essential and a tertiary qualification in technical teaching is needed.

The following are required of EDCR lecturers:

- Teach the subject content with confidence and flair
- Interact with students in a relaxed but firm manner
- Manage the workshop resourcing, budget and safety
- Manage the teaching environment
- Conduct stocktaking and inventory
- Plan for practical work
- Plan for theory lessons
- Conduct weekly practical sessions
- Maintain and service the workshop as a whole

- Maintain and service the tools and instruments
- Ensure students' safety
- Produce working practical assessment tasks (PATs) and integrated science and technology (ISAT) projects in cooperation with students
- Carry out internal continuous assessment (ICASS)
- Implement innovative methods to keep the subject interesting
- Be self-motivated to keep abreast of the latest technological developments
- Regularly attend skills workshops.

Staff development in terms of updating teaching, learning and assessment skills is required on an ongoing basis, particularly for staff members who have moved from industry into the educational environment of an FET college.

5.3 Other resources

The college should have funding available to provide the following:

- Consumables required to perform practical assignments and examinations
- Maintenance of physical recourses
- Purchasing of new equipment.

In EDCR, students are required to work individually on a computer during contact time and they need access to the Internet.

A particular laboratory environment conducive to the presentation of the robotics/electronic practical content is also required.

5.4 Management plan, infrastructure, equipment and finance

Colleges must have the infrastructure and finances as well as a management plan for the subject to address the following:

- Initial capital layout for setting up a computer and electronics laboratory with the necessary work desks and layout
- Physical resources:
  - Lecture room(s)
  - Training area/Work area
  - Ablution facilities
  - Safe storeroom to be equipped with enough storage space for consumables suitable for storage
  - Funds, from learning provider or funding bodies, need to be made available for the procurement of consumables, tools and equipment to allow the effective operation of a workplace involved in a training programme – students need to be individually equipped with the necessary tools
- LTSM:
  Learning materials must conform to approved training and industrial standard requirements and articulate to higher education. LTSM and resources are needed for both academic and practical aspects of learning, and include the following:
  - Comprehensive texts for student use as well as for supplementary reading

  - Various robotic kits and electronic equipment
  - Learning materials for projection during lectures
  - Facilities to support the promotion of opportunities for research by both students and lecturers
  - Educational tours to relevant learning venues
  - Educational and motivational talks by members of the industry
  - Visual and audio-visual material
  - Relevant workshop manuals and documentation
  - Models and demonstrations
- Budget:
  - Annual running costs:
    - Breakages and maintenance (regular service plan)
    - Insurance
    - Internet connectivity
  - Sustainability plan:
    - To upgrade or replace equipment every four to five years
    - To meet safety standards in terms of electrical points and distribution boards; surge arrestors should be installed and electrical work within the computer lab must carry a certificate of compliance from an appropriate service provider/authority
    - Anti-theft and fire-safety equipment must be installed in the computer lab
    - For network maintenance and management.

5.5 Sustainable support

EDCR is a subject that requires sustained support. The Electrical Technology workshop requires regular resourcing for the purpose of completion of practical work as well as maintenance.

Resourcing could be subdivided into the following categories:
- Safety equipment
- Tools and equipment
- Consumable materials
- PAT and ISAT resources
- LTSM
- Preventative maintenance
- Maintenance.

Management teams at colleges offering EDCR should take note of the implications that the electrical/electronic workshop has on the budget of the college. While it is common practice to provide a working budget for a workshop, it is imperative to note that the budget should be structured not only to cater for the completion of PATs by the students, but also to allow the lecturer to replenish tools and equipment and acquire consumable materials for experiments, demonstrations and simulations.

Apart from the PAT and ISAT resources that are needed, the lecturer must also be allowed to supplement LTSM in the form of posters, models, examples, videos, periodicals and more.

6. Assessment guidelines

This section provides the lecturer with guidelines to develop and implement a coherent, integrated assessment system for the subject Robotics in the National Certificate (Vocational) (NC(V)). It must be read with the National Policy Regarding Further Education and Training Programmes: Approval of the Documents, Policy for the NC(V) Qualifications at levels 2 to 4 on the National Qualifications Framework (NQF). This assessment guideline will be used for NQF levels 2–4.

This section explains the requirements for the internal and external subject assessment. The lecturer must use this document with the Subject Guidelines: Robotics to prepare for and deliver the Robotics subject. Lecturers should use a variety of resources and apply a range of assessment skills in the setting, marking and recording of assessment tasks.

6.1 Assessment in National Certificates (Vocational)

Assessment in the NC(V) is underpinned by the objectives of the NQF.

These objectives aim to:
- create an integrated national framework for learning achievements;
- facilitate access to and progression within education, training and career paths;
- enhance the quality of education and training;
- redress unfair discrimination and past imbalances and thereby accelerate employment opportunities; and
- contribute to the holistic development of the student by addressing the following:
  - social adjustment and responsibility
  - moral accountability and ethical work orientation
  - economic participation
  - nation building.

The principles that drive these objectives are the following:
- Integration – to adopt a unified approach to education and training that will strengthen the human resources development capacity of the nation
- Relevance – to be dynamic and responsive to national development needs
- Credibility – to demonstrate national and international value and recognition of the qualification and acquired competencies and skills
- Coherence – to work within a consistent framework of principles and certification
- Flexibility – to allow for creativity and resourcefulness when achieving learning outcomes, to cater for different learning styles and to use a range of assessment methods, instruments and techniques
- Participation – to enable stakeholders to participate in setting standards and coordinating the achievement of the qualification
- Access – to address barriers to learning at each level to facilitate students' progress
- Progression – to ensure that the qualification framework permits individuals to move through the levels of the national qualification via different, appropriate combinations of the components of the delivery system

- Portability – to enable students to transfer credits of qualifications from one learning institution and/or employer to another institution or employer
- Articulation – to allow vertical and horizontal mobility in the education system when accredited prerequisites have been successfully completed
- Recognition of prior learning – to grant credits for a unit of learning following an assessment or if a student possesses the capabilities specified in the outcomes statement
- Validity of assessments – to ensure that assessment covers the broad range of SKVAs needed to demonstrate applied competency, which is achieved through:
  - clearly stating the outcome to be assessed;
  - selecting the appropriate or suitable evidence;
  - matching the evidence with a compatible or appropriate method of assessment; and
  - selecting and constructing an instrument(s) of assessment
- Reliability – to ensure that assessment practices are consistent so that the same result or judgement is arrived at if the assessment is replicated in the same context; this demands consistency in the interpretation of evidence and therefore careful monitoring of assessment is vital
- Fairness and transparency – to verify that no assessment process or method(s) hinder(s) or unfairly advantage(s) any student; the following could constitute unfairness in assessment:
  - Inequality of opportunities, resources or teaching and learning approaches
  - Bias based on ethnicity, race, gender, age, disability or social class
  - Lack of clarity regarding learning outcome being assessed
  - Comparison of a student's work with that of other students based on learning styles and language
- Practicability and cost-effectiveness – to integrate assessment practices within an outcomes-based education and training system and strive for cost- and time-effective assessment.

6.2 Assessment framework for vocational qualifications

The assessment structure for the NC(V) qualification is as follows:

Internal continuous assessment

SKVAs are assessed throughout the year using assessment instruments such as projects, tests, assignments, investigations, role play and case studies. The ICASS practical component is undertaken in a real workplace, a workshop or a structured environment. This component is moderated internally and externally quality-assured by Umalusi. All ICASS evidence is kept in a portfolio of evidence (PoE) and must be readily available for monitoring, moderation and verification purposes.

External summative assessment

The external summative assessment (ESASS) is either a single or a set of written papers set to the requirements of the subject learning outcomes. The Department of Higher Education and Training administers the theoretical component according to relevant assessment policies.

A compulsory component of ESASS is the integrated summative assessment task (ISAT). This assessment task draws on the students' cumulative learning throughout the year. The task requires integrated application of competence and is executed under strict assessment conditions. The task should take place in a simulated or structured environment. The ISAT is the most significant test of students' ability to apply their acquired knowledge.

ESASSs will be conducted annually between October and December, with provision made for supplementary sittings.

6.3 Moderation of assessment

Internal moderation

Assessment must be moderated according to the internal moderation policy of the Technical and Vocational Education and Training college. Internal college moderation is a continuous process. The moderator's involvement starts with the planning of assessment methods and instruments and follows with continuous collaboration with and support to the assessors. Internal moderation creates common understanding of assessment standards and maintains these across vocational programmes.

External moderation

External moderation is conducted by the Department of Higher Education and Training, Umalusi and, where relevant, an Education and Training Quality Assurance (ETQA) body according to South African Qualifications Authority and Umalusi standards and requirements.

The external moderator:

- monitors and evaluates the standard of all summative assessments;
- maintains standards by exercising appropriate influence and control over assessors;
- ensures that proper procedures are followed;
- ensures that summative integrated assessments are correctly administered;
- observes a minimum sample of 10 to 25% of summative assessments;
- gives written feedback to the relevant quality assessor; and
- moderates in case of a dispute between an assessor and a student.

Policy on inclusive education requires that assessment procedures for students who experience barriers to learning be customised and supported to enable these students to achieve their maximum potential.

6.4 Period of validity of ICASS

The period of validity of the ICASS mark is determined by the National Policy on the Conduct, Administration and Management of the Assessment of the National Certificates (Vocational). The ICASS must be resubmitted with each examination enrolment for which it constitutes a component.

6.5 Assessor requirements

Assessors must be subject specialists and should ideally be declared competent against the standards set by the Education, Training and Development Practices Sector Education and Training Authority. If the lecturer conducting the assessments has not been declared a competent assessor, an assessor who has been declared competent may be appointed to oversee the assessment process to ensure the quality and integrity of assessments.

6.6 Types of assessment

Assessment benefits the student and the lecturer. It informs students about their progress and helps lecturers make informed decisions at different stages of the learning process. Depending on the intended purpose, different types of assessment can be used.

- **Baseline assessment**
  At the beginning of a level or learning experience, baseline assessment establishes the SKVAs that students bring to the classroom. This knowledge assists lecturers to plan learning programmes and learning activities.
- **Diagnostic assessment**
  This assessment diagnoses the nature and causes of learning barriers experienced by specific students. It is followed by guidance, appropriate support and intervention strategies. This type of assessment is useful to make referrals for students requiring specialist help.
- **Formative assessment**
  This assessment monitors and supports teaching and learning. It determines students' strengths and weaknesses and provides feedback on progress. It determines whether a student is ready for summative assessment.
- **Summative assessment**
  This type of assessment gives an overall picture of students' progress at a given time. It determines whether the student is sufficiently competent to progress to the next level.

6.7 Planning assessment

An assessment plan should cover three main processes:

- **Collecting evidence**
  The assessment plan indicates which subject outcomes and assessment standards will be assessed, what assessment method or activity will be used and when this assessment will be conducted.
- **Recording**
  Recording refers to the assessment instruments or tools with which the assessment will be captured or recorded. Therefore, appropriate assessment instruments must be developed or adapted.
- **Reporting**
  All the evidence is put together in a report to deliver a decision for the subject.

6.8 Methods of assessment

Methods of assessment refer to who carries out the assessment and includes lecturer assessment, self-assessment, peer assessment and group assessment.

LECTURER ASSESSMENT	The lecturer assesses students' performance against given criteria in different contexts, such as individual work, group work, etc.
SELF-ASSESSMENT	Students assess their own performance against given criteria in different contexts, such as individual work, group work, etc.
PEER ASSESSMENT	Students assess another student's or group of students' performances against given criteria in different contexts, such as individual work, group work, etc.
GROUP ASSESSMENT	Students assess the individual performance of other students within a group or the overall performance of a group of students against given criteria.

6.9 Instruments and tools for collecting evidence

All evidence collected for assessment purposes is kept or recorded in the student's PoE.

The table below summarises a variety of methods and instruments for collecting evidence. A method and instrument are chosen to give students ample opportunity to demonstrate that the subject outcome has been attained. This will only be possible if the chosen methods and instruments are appropriate for the target group and the specific outcome being assessed.

	METHODS FOR COLLECTING EVIDENCE		
	OBSERVATION-BASED (LESS STRUCTURED)	**TASK-BASED** (STRUCTURED)	**TEST-BASED** (MOST STRUCTURED)
ASSESSMENT INSTRUMENTS	• Observation • Class questions • Lecturer, student, parent discussions	• Assignments or tasks • Projects • Investigations or research • Case studies • Practical exercises • Demonstrations • Role play • Interviews	• Examinations • Class tests • Practical examinations • Oral tests • Open-book tests
ASSESSMENT TOOLS	• Observation sheets • Lecturer's notes • Comments	• Checklists • Rating scales • Rubrics	• Marks (e.g. %) • Rating scales (1–7)
EVIDENCE	• Focus on individual students • Subjective evidence based on lecturer observations and impressions	**Open middle:** Students produce the same evidence but in different ways **Open end:** Students use the same process to achieve different results	Students answer the same questions in the same way, within the same time

6.10 Tests

A test could be a practical test (design- and development-oriented) or a written test. The programme of assessment should reflect a balance between practical and written tests. Tests could include open-book tests.

A test for formal assessment should not comprise a series of small tests, but should cover a substantial amount of content and the duration should be a minimum of 60 minutes.

Open-book tests require students to find information and apply knowledge and skills. Students are tested on understanding and application of learning material and not on rewriting. Open-book tests should not include only short questions. They must include questions/tasks that will encourage thinking and decision making.

For written open-book tests, students are required to write longer reflective answers, such as paragraph-type responses to a given scenario. Paragraphs providing reasons and supporting evidence/arguments are essential.

For practical open-book tests, students are required to apply a combination of a series of procedures and techniques to new situations in order to provide a specific answer or accomplish a specific goal.

Alternative assessment

Alternative assessment is an alternative to standard tests and exams. It provides a true evaluation of what students have learned, going beyond acquired knowledge by looking at their application of this knowledge.

Integrated task/test

An integrated task/test requires students to be able to apply their knowledge and skills in both the theory and the practical work that was covered. Testing these types of scenarios include, for example database theory together with database practical, algorithm with implementation and using a trace table to debug a programme.

Case study

Case studies are investigations of a real-life situation or simulation thereof. Data are gathered from a variety of sources and by using several different methods. A case study requires an in-depth and detailed examination of a scenario, as well as the related contextual conditions.

Each test, open-book test, alternative assessment task and examination must reflect different cognitive levels.

6.11 Tools for assessing student performance

Rating scales are marking systems where a symbol (such as 1 to 7) or a mark (such as 5/10 or 50%) is defined in detail. The detail is as important as the coded score. Traditional marking, assessment and evaluation mostly used rating scales without details such as what was right or wrong, weak or strong, etc.

Task lists and checklists show the student what needs to be done. These consist of short statements describing the expected performance in a particular task. The statements on the checklist can be ticked off when the student has adequately achieved the criterion. Checklists and task lists are useful in peer or group assessment activities.

Rubrics are a hierarchy (graded levels) of criteria with benchmarks that describe the minimum level of acceptable performance or achievement for each criterion. Using rubrics is a different way of assessing and cannot be compared to tests. Each criterion described in the rubric must be assessed separately. Two types of rubrics are mainly used, namely the holistic or the analytical rubric.

6.12 Selecting and/or designing recording and reporting systems

The selection or design of recording and reporting systems depends on the purpose of recording and reporting student achievement. Why particular information is recorded and how it is recorded determine which instrument will be used.

Computer-based systems, for example spreadsheets, are cost- and time-effective. The recording system should be user-friendly, and information should be easily accessed and retrieved.

6.13 Competence descriptions

All assessment should award marks to evaluate specific assessment tasks. However, marks should be awarded against rubrics and not simply be a total of ticks for right answers. Rubrics should explain the competence level descriptors for the SKVAs that a student must demonstrate to achieve each level of the rating scale.

When lecturers or assessors prepare an assessment task or question, they must ensure that the task or question addresses an aspect of a subject outcome. The relevant assessment standard must be used to create the rubric to assess the task or question. The descriptions must clearly indicate the minimum level of attainment for each category on the rating scale.

6.14 Strategies for collecting evidence

A number of different assessment instruments may be used to collect and record evidence. Examples of instruments that can be (adapted and) used in the classroom include the following:

- **Record sheets**
  The lecturer observes students working in a group. These observations are recorded in a summary table at the end of each project. The lecturer can design a record sheet to observe students' interactive and problem-solving skills, attitudes towards group work and involvement in a group activity.
- **Checklists**
  Checklists should have clear categories to ensure that the objectives are effectively met. The categories should describe how the activities are evaluated and against what criteria they are evaluated. Space for comments is essential.

6.15 Schedule of assessment

At NQF levels 2, 3 and 4, lecturers will conduct assessments as well as develop a schedule of formal assessments that will be undertaken in the year. All three levels also have an external examination that accounts for 50% of the total mark. The marks allocated to assessment tasks completed during the year, kept or recorded in a PoE, account for the other 50%.

The PoE and the external assessment include practical and written components. The practical assessment in Principles of Computer Programming must, where necessary, be subjected to external moderation by Umalusi or an appropriate ETQA body, appointed by the Umalusi Council in terms of Section 28(2) of the General and Further Education and Training Quality Assurance Act No. 58 of 2001.

6.16 Recording and reporting

The subject EDCR, as is the case for all the other vocational subjects, is assessed according to five levels of competence. The level descriptions are explained in the following table:

RATING CODE	RATING	MARKS %
5	Outstanding	80–100
4	Highly competent	70–79
3	Competent	50–69
2	Not yet competent	40–49
1	Not achieved	0–39

The programme of assessment should be recorded in the lecturer's portfolio of assessment for each subject. The portfolio should at least include the following:

- Contents page
- Formal schedule of assessment
- Requirements for each assessment task
- Tools used for each assessment task
- Recording instrument(s) for each assessment task
- Mark sheet and report for each assessment task.

The college must standardise these documents. The student's PoE must include at least the following:

- Contents page
- Assessment tasks according to the assessment schedule.

6.17 Specifications for external assessment in EDCR

Background

The NC(V) qualification comprises an internal and an external assessment component that both have a weighting of 50%. The internal assessment component is made up of the ICASS tasks only, while the external assessment component is made up of the ISAT and an external examination for vocational subjects.

COMPONENT	WEIGHTING PER COMPONENT	TASK	WEIGHTING PER TASK
Internal assessment	50%	ICASS	50%
External assessment	50%	ISAT	15%
		External examination	35%

Practical assessments form part of both the ICASS and the ISAT tasks of the NC(V) qualification. While the ISAT accounts for 15% of the final subject mark, it is a common standardised practical task, as it is externally set by the Department. The five assessments comprising the ICASS component of the vocational subjects accounting for 50% of the final subject mark are, however, internally set and therefore vary in standard from one institution to the next.

Two of these five ICASS assessments are practical in nature and make up 50% of the ICASS mark, which represents 25% of the final subject mark.

ICASS TASK	QUANTITY	WEIGHTING OF ICASS
Tests	2	10% × 2 = 20%
Practical assessments	2	25% × 2 = 50%
Internal examination	1	30%

In 2017, the two PATs forming part of the ICASS were standardised to ensure a uniform standard across institutions and to improve the chances of employment of NC(V) graduates in the workplace. New subject ISATs were simultaneously introduced in order to facilitate unhindered progression between NC(V) levels in accordance with the NC(V) policy on admission and progression.

The NC(V) policy further requires that assessment tasks must be reviewed on a regular basis to ensure continual relevance, credibility, validity and fairness. The initial PATs have now been reviewed to assess new curriculum content introduced in 2019. The two reviewed practical ICASS assessments as well as the reviewed ISAT contained in this document must be implemented in 2019.

The practical assessments for the ICASS and ISAT tasks are to be implemented as a series of three practical tasks per vocational subject to ensure that the practical competencies prescribed per subject are assessed in an authentic practical context that focuses on applied competence.

TASK NO.	PRACTICAL ASSESSMENT
1	ICASS PAT 1
2	ICASS PAT 2
3	ISAT

Purpose and value of practical assessments to the workplace

The practical ISAT and ICASS assessments play a central role in expressing the vocational nature of the NC(V) qualification, as they require the demonstration of the practical application of theoretical knowledge through the performance of assessment tasks that replicate or simulate a workplace or real-life process and/or product. Performance in these practical assessments is therefore used by industry as a measure to determine readiness of NC(V) graduates to enter the workplace.

Integrated summative assessment task

A compulsory component of the ESASS is the ISAT. The ISAT draws on the students' cumulative learning achieved throughout the year. The task requires integrated application of competence and is executed and recorded in compliance with assessment conditions.

Principles for the conduct of practical assessments

The following principles are applicable to the conduct of practical assessments:

- Each student must be provided with a copy of a subject assessment schedule that includes all three practical assessments (see ICASS guidelines).
- The criteria to be used to assess student performance in a practical assessment must be made available to the students and be explained prior to the conduct of each practical assessment.
- All practical assessments, i.e. performance-based and/or creation of product/artefact, must be undertaken in controlled conditions under the direct supervision of the subject lecturer.
- An internal moderator must moderate at least 10% or a minimum of five performance-based assessments during the actual performance.
- Practical assessments must take place in suitable environments relevant to the task specifications, e.g. workshop, computer laboratory, simulator or actual workplace.

7. National examination

A national examination is conducted annually in October or November by means of a paper(s) set and moderated externally. The following distribution of cognitive application is suggested:

Cognitive and difficulty levels of formal assessments

Formal assessments must cater for a range of cognitive levels and abilities of students, as shown in the table on the next page.

COGNITIVE LEVEL	TAXONOMY	DESCRIPTION
C1	Knowledge, remembering	Recall of factual/process knowledge in isolation, i.e. one step/set of basic steps/instruction/process at a time, e.g. definitions in the theory paper and known procedures/ algorithms in the practical paper. It also presents the knowledge of the various theoretical components and subject content relating to the composition and design of EDCR-based systems. These include: • knowledge about the various components and constituents of a robot; • design-related aspects and considerations; and • knowledge of the applicability and application of formulas.
C2	Understanding, applying	Demonstrates understanding of: • steps/algorithms/processes/ isolatable bits, such as translating from one form of representation to another, e.g. converting a flow chart representation of a program/program segment to a functional program; and • various components and their applications, uses and common properties It also requires using known routines/algorithms/ processes/design constructs and components in a familiar context in order to complete a task, where all of the information required is immediately available to the student.
C3	Analysing, evaluating, creating	Requires reasoning/investigation/developing a plan or sequence of steps/algorithms or electronics-related artefact in the form of a component; has some complexity where students need to see how parts relate to a whole; organising/putting together component parts/elements to form a coherent functional whole/ achieving an overall objective and completing a task could have more than one possible approach. It could also require weighing possibilities, deciding on the most appropriate solution, as well as testing to locate errors/troubleshooting, pattern recognition and generalisation. These questions will comprise actions/strategies/ procedures where students are required to create their own solutions to challenges they may encounter. These questions could include analysing questions or data and decision making.

Levels of difficulty (D) are categorised as follows:

D1: Easy for the average student (in relation to the subject levels 2 to 4) to answer

D2: Moderately challenging for the student (in relation to the subject levels 2 to 4) to answer

D3: Difficult for the average student (in relation to the subject levels 2 to 4) to answer

D4: Very difficult for the average student (in relation to the subject levels 2 to 4) to answer. The skills and knowledge required to answer questions at this level should be included to distinguish among high achievers.

Questions in the formal assessment tasks will assess performance at different cognitive levels, critical thinking skills, problem-solving techniques and difficulty, as outlined below.

In judging the level of difficulty of each question, both the demands that each question makes on the cognitive ability of an average EDCR student and the intrinsic level of difficulty of the question or task are considered. In making this judgement, the difficulty or ease of a particular question is identified. A four-category framework for thinking about question or item difficulty adapted from Leong (2006) has been used in this identification process. This framework comprises the following four general categories of difficulty:

- **Content difficulty:** This indexes the difficulty of the subject matter, topic or conceptual knowledge; some content is inherently more difficult than other content.
- **Stimulus difficulty:** This relates to the linguistic features of the question and the challenge that students face in reading, interpreting and understanding the question.
- **Task difficulty:** This refers to the difficulty that students face when trying to formulate or produce an answer.
- **Expected response difficulty:** This refers to difficulties because of the mark scheme or marking guidelines, in other words how marks are to be allocated.

Weighting of cognitive levels and difficulty levels

Papers 1 and 2 will include questions across three cognitive levels. The distribution of cognitive levels in the practical and theory papers is given in the table below.

COGNITIVE LEVEL	DESCRIPTION	PAPER 1 (DESIGN-RELATED)	PAPER 2 (THEORY)
1	Knowledge and remembering	30%	30%
2	Understanding and applying	40%	40%
3	Analysing, evaluating and creating	30%	30%

The estimated percentages for each level of difficulty (D) within each cognitive level (C) are shown in the table below.

	D1	D2	D3	D4	TOTAL
C1	±10%	±10%	±10%	–	**±30%**
C2	±15%	±15%	±8%	±2%	**±40%**
C3	±15%	±7%	±5%	±3%	**±30%**
TOTAL	**±40%**	**±32%**	**±23%**	**±5%**	**100%**

Students are required to investigate and analyse problems in a variety of contexts (such as scientific, technological, environmental and everyday life contexts) in order to solve the described problems effectively, either via design and development of a solution or an EDCR-related artefact in Paper 1 or described proposed solutions in Paper 1/Paper 2.

Examinations

LEVEL	PAPER 1 (THEORY)	PAPER 2 (DESIGN-RELATED)
2	100 marks 3 hours	80 marks 3 hours
3	100 marks 3 hours	80 marks 3 hours
4	100 marks 3 hours	80 marks 3 hours

Weighting of the topics for the exams

Level 2

LEVEL 2	PAPER 1 (THEORY)	PAPER 2 (DESIGN-RELATED)
Topic 1: SI units and introduction to atomic theory	15%	5%
Topic 2: Electrical supply systems, Ohm's law, Joule's law and related theoretical aspects	15%	10%
Topic 3: Basic electronic components and semiconductors	15%	30%
Topic 4: Electrical components, symbols, circuit drawings, prototyping and design	15%	30%
Topic 5: Electronic tools and equipment	15%	
Topic 6: Digital systems and principles	15%	25%
Topic 7: Workshop ethics, Save use of equipment and operational health and safety	10%	

Final exam mark

(Mark for Paper 1 + Paper 2) / (combined paper total) × 100

8. Standardisation and considerations

For educational and training purposes, careful consideration should be given to selecting tools, components, hardware and software across the curriculum for the different levels.

The motivation regarding the use of standardised tools and hardware resides in the following points as it helps ensure:

- fair teaching and learning and setting of fair examination papers, and
- stability/compatibility during examinations.

In addition, other motivational factors are discussed below.

8.1 National exam paper setting

Problems that exam panels can experience if different tools/components/hardware and software are used with different features and configurations. The complexities to synchronise the different tools and versions when setting practical papers impact on content coverage and cognitive demand and/or time required in answering questions.

8.2 Marking of exams

Not standardising implies that markers need to know each of the available components and if colleges do not standardise, marking could become very difficult.

8.3 Migration of lecturers and students

Students and lecturers moving from one college to another could be faced with challenges if they do not have the necessary prerequisite knowledge or knowledge of the new tools or hardware being used.

8.4 Lecturer support

Good information and communication technology lecturers are very scarce and subject support is very specialised. With standardised tools, lecturer support is less troublesome. This is also true for lecturer training programmes.

8.5 Technical support

This is also made difficult in terms of license agreements, setup, advise, etc.

9. Work schedule

WEEK	MODULE	TOPICS	ACTIVITIES	TIME ALLOCATION
1–2	**Module 1** SI units and introduction to atomic theory	1.1 Basic SI units of measurement 1.2 Basic atomic theory	Activity 1.1 Activity 1.2 Activity 1.3 Summative assessment	20 hours
3–5	**Module 2** Electrical supply systems, Ohm's law, Joule's law and related theoretical aspects	2.1 Recognise and use basic SI units of measurement 2.2 Comparing different electrical supply systems 2.3 Calculations based on the grouping of electrical cells	Activity 2.1 Activity 2.2 Summative assessment	25 hours
5–9	**Module 3** Basic electronic components and semiconductors	3.1 Basic electronic components 3.2 Semiconductors 3.3 Formation of P- and N-type junctions (PN-junctions) 3.4 Different types of diodes 3.5 The use and implementation of transistors 3.6 Integrated circuits 3.7 Transducers and sensors	Activity 3.1 Activity 3.2 Activity 3.3 Summative assessment	45 hours
10–14	**Module 4** Electrical components, symbols, circuit drawings, prototyping and design	4.1 Symbols of electronic components (elementary circuit drawings) 4.2 Constructing simple circuits on breadboards and Veroboards 4.3 The composition and design of electric circuits	Activity 4.1 Activity 4.2 Summative assessment	45 hours
14–15	**Module 5** Electronic tools and equipment	5.1 Using basic electronic tools and measuring equipment 5.2 Testing electronic components	Activity 5.1 Activity 5.2 Summative assessment	15 hours
16–19	**Module 6** Digital systems and principles	6.1 Basic digital concepts 6.2 Logic design 6.3 Using logic gates	Activity 6.1 Activity 6.2 Activity 6.3 Summative assessment	40 hours
20	**Module 7** Workshop ethics, safe use of equipment and operational health and safety	7.1 Understanding occupational health and safety concepts 7.2 Safety precautions and procedures when replacing components	Activity 7.1 Activity 7.2 Summative assessment	10 hours
TOTAL				**200 hours**

Module 1

SI units and introduction to atomic theory

After students have completed this module, they should be able to:

- identify basic units of measurement used in engineering;
- define the physical quantities that are measured by the SI units;
- describe the rules when writing SI units of measurement;
- convert scientific notation to decimal notation and vice versa (convert answers to three decimal digits);
- list common prefixes used in engineering;
- derive new units from the relationships between SI units;
- explain with the aid of a sketch the structure of an atom;
- define *atomic number* and *atomic mass*;
- explain how electrons are distributed in an atom;
- explain the concepts of atomic theory; and
- explain the methods of bonding in an atom.

Introduction

Accurate measurement is a fundamental component of good science, engineering and technology as well as many other areas of work. Regardless the field in which one specialises, there is a need to speak a common language when it comes to measurements. An international unit of standards, the International System of Units, has been adopted across all fields of engineering. The first half of this module focuses on the SI units of measurement.

Atomic theory serves as the foundation of many engineering and science subjects. It helps us to understand why materials have different properties and why some materials bond with others. In the second half of this module, students will learn more about the structure of an atom and how atoms interact and bond.

Activity 1.1

SB page 5

1. **Why is it important that all countries use a standardised system of measurements?**

   A standardised system will allow us to make direct comparisons using the same units to record data, do calculations and report results.

2. **What is the international standard system of measurement called?**

   The International System of Units or the SI system

3. **List the SEVEN base units of the abovementioned system and next to each unit write the correct abbreviation.**

   - Length in metre (m)
   - Time in seconds (s)
   - Mass in kilogram (kg)
   - Temperature in kelvin (K)
   - Electric current in ampere (A)
   - Luminous intensity in candela (cd)
   - Amount of substance in mole (mol)

4. **Copy the table below in your workbook. State whether each of the given values has been expressed correctly and rewrite any incorrect units correctly.**

UNIT	EXPRESSED VALUE	CORRECT/WRONG	CORRECTION
10 degrees Celsius	**10 C**	Wrong	10 °C
120 kilometres	**120 km**	Correct	
20 kilograms	**20 kgs**	Wrong	20 kg
40 seconds	**40 s**	Wrong	40 s
6 kilowatt hours	**6 kWh**	Correct	
16 ampere	**16 amp**	Wrong	16 A
5 newton	**5 n**	Wrong	5 N

Activity 1.2

SB page 12

1. **Write each of the following numbers in scientific notation:**

   1.1 130000

   $1{,}3 \times 10^5$

   1.2 0,000 004

   4×10^{-7}

   1.3 1 080 000 000

   $1{,}08 \times 10^9$

   1.4 0,002 55

   $2{,}55 \times 10^{-3}$

2. **Write the following in decimal notation:**

   2.1 $5{,}05 \times 10^7$

   50 500 000

   2.2 $9{,}7 \times 10^{-4}$

   0,000 97

   2.3 240×10^2

   24 000

3. **Express the following numbers as engineering answers by using the correct prefix.**

WITHOUT PREFIX	WITH PREFIX
E.g. 5 000 m	**5 km**
1 200 Hz	1,2 kHz
0,006 s	6 ms
2 700 000 Ω	2,7 MΩ
20 000 m	20 km
0,25 kg	250 g

4. **Copy the table below in your workbook and complete it by filling in the missing details. Use the correct conventions for writing SI units and their symbols. Pay specific attention to the use of capital letters.**

DERIVED QUANTITY	DERIVED UNIT OF MEASUREMENT	SYMBOL
E.g. Area	**square metre**	**m^2**
Force	square metre	m^2
Power	newton	N
Speed/Velocity	watt	W
Potential difference	metre per second	m/s
Volume	volt	V

Activity 1.3

SB page 17

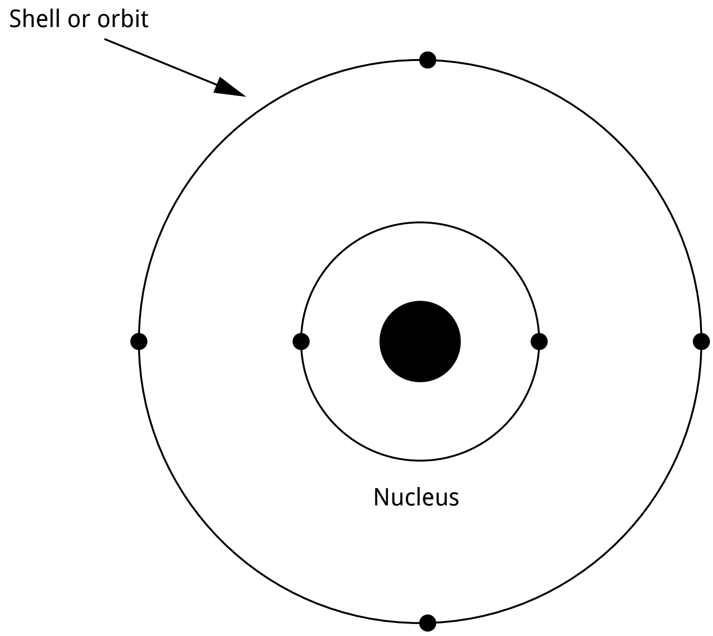
1. 1.1 **Define the term *atom*.**

It is the smallest part of a chemical element that can exist. (An atom is a building block of matter. It is the smallest particle into which a substance can be divided without changing its properties. An atom cannot be broken apart using any chemical means.)

1.2 **Describe the THREE basic parts of an atom.**

Protons, neutrons and electrons

1.3 **Draw a diagrammatical representation of an atom that has two shells. The inner shell has two electrons and the outer shell four.**



2. **What does the atomic number of an element determine?**

The number of protons determines an element's atomic number (Z) and distinguishes one element from another.

3. **Explain the term *atomic mass*.**

   An element's atomic mass (A) is the sum of the number of protons and the number of neutrons.

Summative assessment

SB page 26

1. **Name the standardised units of metric measurements used worldwide.**

   SI units/International System of Units **(1)**

2. **State whether each of the following is (a) a base unit or (b) a derived unit:**

   2.1 Temperature in kelvin

   Base unit

   2.2 Electric current in ampere

   Base unit

   2.3 Force in newton

   Derived unit

   2.4 Area in square metre

   Derived unit

   2.5 Length in metre

   Base unit **(5 × 1)** (5)

3. **It is important that we follow the prescribed international rules when expressing units or derived units. Rewrite the following incorrect measurements correctly:**

   3.1 5 kgs

   5 kg

   3.2 230 Volts

   230 V or 230 volt

   3.3 16 amps

   16 A or 16 ampere

   3.4 2 000 000 Hz

   2 GHz

   3.5 The Newton is the unit of force.

   newton **(5 × 1) (5)**

4. **Rewrite each of the following numbers as a scientific notation:**

   4.1 0,002 4

   $2,4 \times 10^{-3}$

   4.2 53 000 000

   $5,3 \times 10^{7}$

   4.3 0,000 97

   $9,7 \times 10^{-4}$

   4.4 24 000

   24×10^{4} **(4 × 1) (4)**

5. **Write the following in decimal notation:**

   5.1 $7,56 \times 10^{-4}$

   0,000 756

   5.2 18×10^{5}

   1 800 000 **(2 × 1) (2)**

6. **Complete the table below by filling in the missing details as indicated:**

METRIC PREFIX	PREFIX SYMBOL	MULTIPLIER	POWER OF 10
giga	**G**	**1 000 000 000**	10^{9}
kilo	**k**	1 000	$\mathbf{10^{3}}$
nano	N	0,000 000 001	$\mathbf{10^{-9}}$
micro	μ	**0,000 001**	10^{-6}

(8 × ½) (4)

7. **Choose the correct answer from those provided. Write down only the question number and the letter of your choice.**

   7.1 **The nucleus of an atom contains the following:**

   A **Protons, neutrons and electrons**

   B **Electrons and protons**

   C **Valence electrons and protons**

   D **Protons and neutrons**

   7.2 **This part of the atom is positively charged:**

   A **Electron**

   B **Neutron**

   C **Proton**

   D **Nucleus**

   7.3 **This part of the atom is negatively charged:**

   A **Electron** **B** **Neutron**

   C **Proton** **D** **Nucleus**

7.4 **This part of the atom carries no charge:**

A	**Electron**	**B**	**Neutron**
C	**Proton**	**D**	**Nucleus**

7.5 **These two parts of an atom have the same mass:**

A **Electron and neutron**

B **Electron and proton**

C **Proton and neutron** **(5 × 1) (5)**

8. **Explain each of the following terms:**

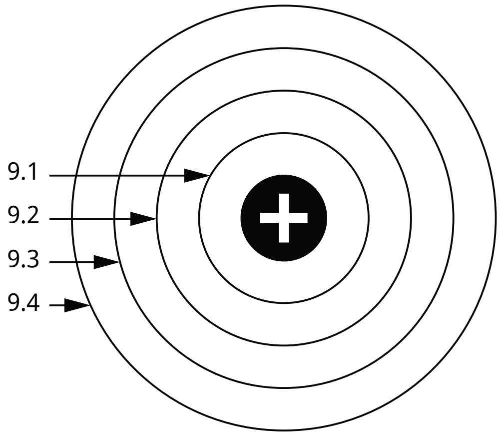
8.1 **Atomic mass**

An element's mass number (A) is the sum of the number of protons and the number of neutrons. The small contribution of mass from electrons is disregarded when calculating the mass number. **(2)**

8.2 **Atomic number**

It is the number of protons in the nucleus, which determines what type of element it is. **(2)**

9. **Use the illustration of the energy levels of an atom below to complete the table given.**



	STATE THE ENERGY LEVEL OF THE SHELL (ONE, TWO, THREE OR FOUR)	PROVIDE THE DESIGNATED LETTER OF EACH LEVEL	STATE THE MAXIMUM NUMBER OF ELECTRONS THE ENERGY LEVEL CAN CONTAIN
9.1	1	k	2
9.2	2	l	8
9.3	3	m	18
9.4	4	n	$\frac{32}{8}$

(3 × 4) (12)

10. Explain the term *valence electron*.

A valence electron is a negatively charged particle in the shell (energy level) that is furthest away from the nucleus of the atom. **(2)**

11. Describe how an atom is ionised.

When an atom gains or loses one or more electrons, it is said to be ionised. The atom will have an overall negative or overall positive charge and is called an ion. **(2)**

12. If an atom has six protons, how many electrons will it have in its normal state?

Six **(1)**

13. 13.1 What is the difference between a *conductor* and an *insulator*?

A conductor allows the flow of electrons, while an insulator does not allow any movement of electrons. **(2)**

13.2 Give TWO examples of conductors.

Any TWO: Silver, copper, gold, aluminium, tungsten, brass, wrought iron, steel, lead, cast iron, mercury **(2)**

13.3 Give TWO examples of insulators.

Any TWO: Rubber, glass, pure water, oil, air, diamond, dry wood, dry cotton, plastic **(2)**

14. 14.1 Explain the term *semiconductor*.

A semiconductor is a material that can conduct under certain conditions (be a conductor) and not conduct under other conditions (an insulator). A material that possesses these qualities (characteristics) is called a semi-conductor. **(3)**

14.2 Name THREE types of materials used as semiconductors.

Silicon (Si), germanium (Ge) and a compound called gallium arsenide. **(3)**

15. Name THREE types of bonding in atoms, and briefly explain each type.

- Ionic bonding – Electrons can be transferred from one atom to another
- Covalent bonding – Electrons can be shared between neighbouring atoms
- Metallic bonding – Electrons can be shared with all atoms in a material **(6)**

TOTAL: 65

Module 2

Electrical supply systems, Ohm's law, Joule's law and related theoretical aspects

After students have completed this module, they should be able to:

- explain what Ohm's law is and identify the formula used for calculations;
- explain what Joule's law is and identify the formula used for calculations;
- apply the various laws and formulas towards the calculation of different types of values that include:
  - resistance
  - energy
  - power

  using the correct formulae and units of measurement;
- explain, with examples, the difference between direct current (DC) and alternating current (AC);
- explain, with practical examples, types of DC sources;
- sketch and explain lead-acid batteries as follows:
  - operating principles
  - proper use
  - maintenance;
- explain the concepts *continuity* and *current flow*;
- identify closed and open circuits from examples;
- predict whether current flow is possible;
- explain concepts regarding sources of electrical power; and
- perform calculations on typical circuits involving the grouping of cells, using practical examples.

Introduction

The electrical field is very vast and includes many electrical concepts, definitions and laws. Without a good understanding of the basic concepts, definitions and laws, students will find it difficult to master any electrical subject. In this module, they will learn more about Ohm's law, Joule's law, alternating current (AC) and direct current (DC) as well as different types of cells.

Activity 2.1

SB page 35

1. **Define *Ohm's law*.**

   The current flowing through a circuit is directly proportional to the voltage and inversely proportional to the resistance, provided the temperature remains constant.

2. **Briefly explain the relationship between heat, current, resistance and time within an electric circuit.**

   The amount of heat generated (H) in a conductor of resistance (R) when a current (I) flows through it for a time (t) is directly proportional to the square of the current, the resistance of the conductor and the time for which the current flows. $H = I^2Rt$ joules (J)

3. **A series circuit consists of an unknown resistor, a 24-V power supply and a switch. The current flowing through the circuit when the switch is closed is 2,4 A. Calculate the value of the unknown resistor.**

   $$R = \frac{V}{I}$$
   $$= \frac{24}{2{,}4}$$
   $$= 10\ \Omega$$

4. **A series circuit consists of a 4,7-kΩ resistor and a 12-V battery supply. The current flowing through the circuit is 350 mA. Calculate the energy consumed by the resistor if the current flows through the resistor for 45 seconds.**

   $$E = VIt$$
   $$= 12 \times 0{,}350 \times 45$$
   $$= 189\ J$$

5. **The current flowing through a 50-W lamp for three minutes is 2,5 A. Calculate the heat energy produced in the lamp.**

   $$E = Pt$$
   $$= 50 \times 180$$
   $$= 9\ 000\ J \text{ or } 9\ kJ$$

6. **The element of an electric kettle has a resistance of 40 Ω and draws a current of 5 A. Calculate the power rating of the kettle.**

   $$P = I^2 \times R$$
   $$= (5)^2 \times 40$$
   $$= 1\ 000\ W \text{ or } 1\ kW$$

7. The element of a geyser has a resistance of 50 Ω. It is connected to a 220-V supply. Calculate the power consumed by the element.

$$P = \frac{V^2}{R}$$
$$= \frac{220^2}{50}$$
$$= 968 \text{ W}$$

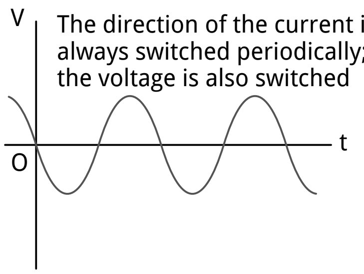
Activity 2.2

SB page 44

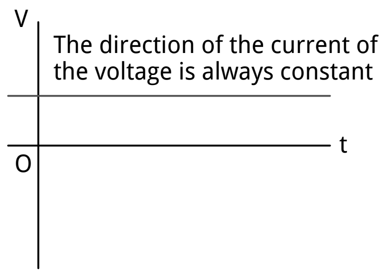
1. 1.1 Explain the difference between *AC* and *DC*.

AC: The electric charge in the source changes direction periodically.
DC: The electric charge of the source flows in one direction

1.2 Make a simple drawing to illustrate an AC and a DC signal. Label the drawings clearly.



AC



DC

2. Name the THREE main parts of a lead-acid battery.

- Lead dioxide cathode
- Spongy metallic lead anode; and
- Sulphuric-acid solution electrolyte

3. Explain the term *continuity*.

It refers to a complete path for current flow from the positive terminal of the battery to the negative terminal of the battery.

Summative assessment

SB page 50

1. Briefly explain *Ohm's law*.

The current flowing through a circuit is directly proportional to the voltage and inversely proportional to the resistance, provided the temperature remains constan. **(3)**

2. Briefly explain the relationship between heat, current, resistance and time within an electric circuit.

The amount of heat (H) generated in a conductor with a given resistance (R) when a current (I) flows through it for a specific time (*t*) is directly proportional to the square of the current, the resistance of the conductor and the time for which the current flows. **(4)**

3. A 12-V supply is connected to a DC motor as a load that draws 0,25 A. Calculate the resistance value of the DC motor.

$R = \frac{V}{I}$

$= \frac{12}{0,25}$

$= 48\ \Omega$ **(2)**

4. When an electric toaster is plugged into a 220-V supply, it draws a current of 3,5 A. Calculate the resistance of the heating element.

$R = \frac{V}{I}$

$= \frac{220}{3,5}$

$= 62,86\ \Omega$ **(2)**

5. A fan has a power rating of 20 W and is used for one hour. Calculate the total energy transferred.

$E = Pt$

$= 20 \times 3\ 600$

$= 72\ 000$ J or 72 kJ **(2)**

6. Define *power*.

Power can be defined as the ability of an electrical machine to do work because of the applied voltage and the current flow through the machine. **(3)**

7. Calculate the power used by the headlight of a car if it draws 3 A from the 12-V supply battery.

$P = V \times I$

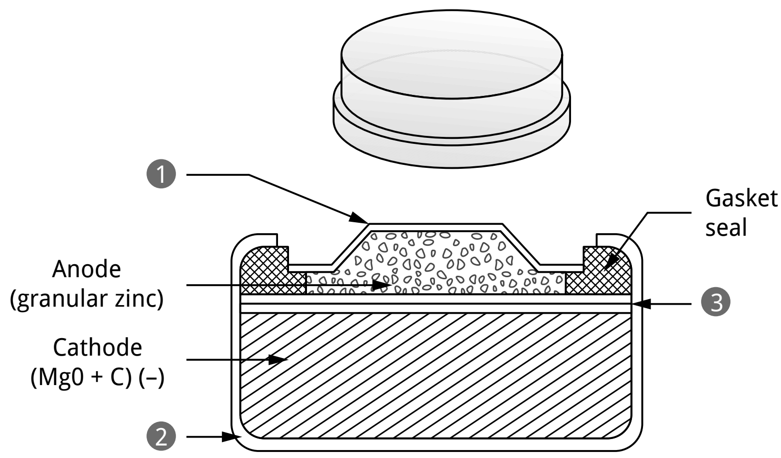
$= 12 \times 3$

$= 36$ W **(2)**

8. 8.1 Identify the cell illustrated below.

Mercury cell **(1)**

8.2 Label the parts numbered 1 to 3.



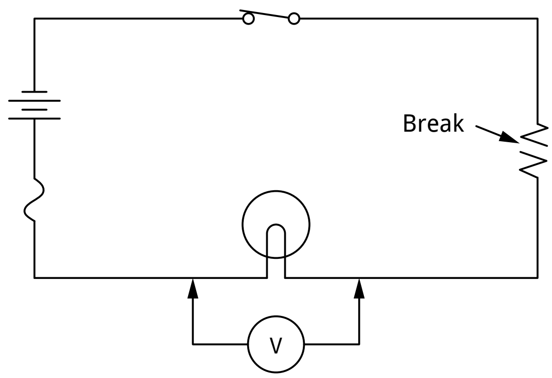
1 – End cap (negative terminal)
2 – Outer can (steel)
3 – Separators **(3)**

9. **List FOUR important details regarding the maintenance of a lead-acid battery.**

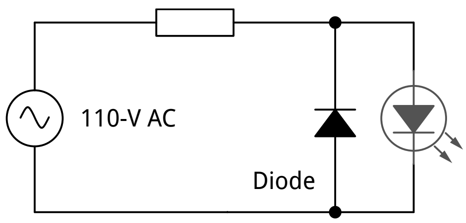
- Lead-acid batteries must be stored in a charged state, once the electrolyte has been introduced, to avoid deterioration of the active chemicals.
- Regularly check the water levels and top it up when needed.
- Never overfill the battery with acid.
- For lead-acid batteries to work for long periods, they must be discharged to no more than half of their total capacity regularly.
- Never allow battery vents to become blocked.
- The battery must be left on trickle or float charge for prolonged periods. Avoid fast charging. (Any 4) **(4)**

10. **10.1 Which of the circuits illustrated below is continuous?**

A



B

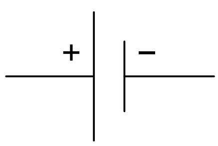


B **(1)**

10.2 Briefly explain your answer to QUESTION 10.1.

There is a break in circuit A. **(1)**

11. **Draw the symbol used to indicate a cell.**



(2)

12. **Discuss the differences between a *primary cell* and a *secondary cell.***

Primary cells: Irreversibly transform chemical energy into electrical energy. When the initial supply of reactants is exhausted, energy cannot be readily restored to the battery by electrical means. Putting it simply, primary cells cannot be recharged.

Secondary cells: Can be recharged; their chemical reaction can be reversed by supplying electrical energy to the cell, thereby restoring their original composition. **(4)**

13. Explain the term *EMF*.

Abbreviation of electromotive force; this is the maximum potential difference between two electrodes of a cell when it is not connected to a circuit. **(4)**

14. Explain how the parallel connection of the cells of a battery would affect each of the following:

14.1 Current-delivering capacity

The current-delivering capacity will increase.

14.2 EMF

The EMF will remain unchanged (total EMF of the battery equals the EMF of one cell).

14.3 Internal resistance

The internal resistance will decrease. **(3 × 1) (3)**

15. A battery consists of four cells, each with an EMF of 2,1 V and an internal resistance of 0,135 Ω. The cells are connected in series. Calculate:

15.1 The total EMF of the battery

$EMF_T = E_1 + E_2 + E_3 + E_4$
$= 2,1 + 2,1 + 2,1 + 2,1$
$= 8,4$ V **(2)**

15.2 The total internal resistance of the battery

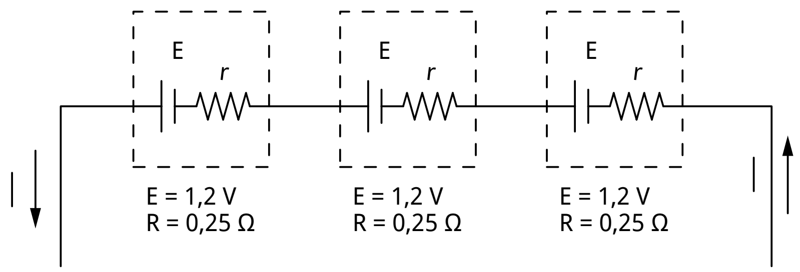
$r_T = r_1 + r_2 + r_3 + r_4$
$= 0,135 + 0,135 + 0,135 + 0,135$
$= 0,54$ Ω **(2)**

16. Refer to the figure below. Calculate:

16.1 The total EMF of the battery

$EMF_T = E_1 + E_2 + E_3$
$= 1,2 + 1,2 + 1,2$
$= 3,6$ V **(2)**

16.2 The total internal resistance of the battery



$r_T = r_1 + r_2 + r_3$
$= 0,25 + 0,25 + 0,25$
$= 0,75$ Ω **(2)**

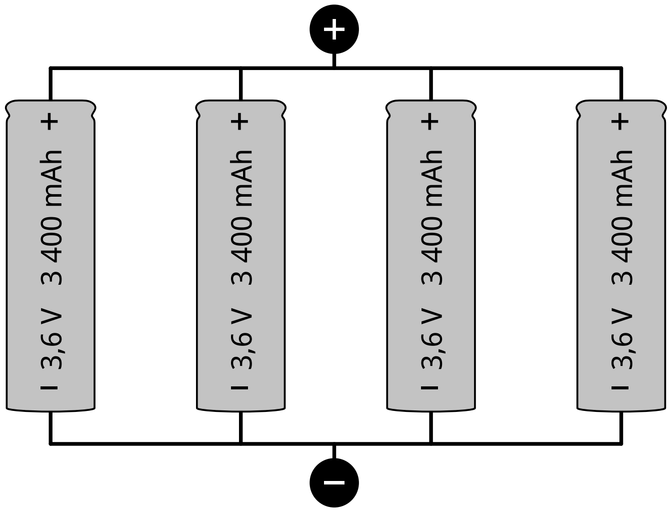
17. A battery pack consists of the cells illustrated in the figure below. Calculate:

17.1 The total EMF of the battery

$EMF_T = E_1 = E_2 = E_3 = E_4$ (the total EMF of the battery equals the EMF of one cell)
$= 1{,}5$ V **(2)**

17.2 The total internal resistance of the battery

$r_1 = r_2 = r_3 = r_4 = 0{,}125\ \Omega$

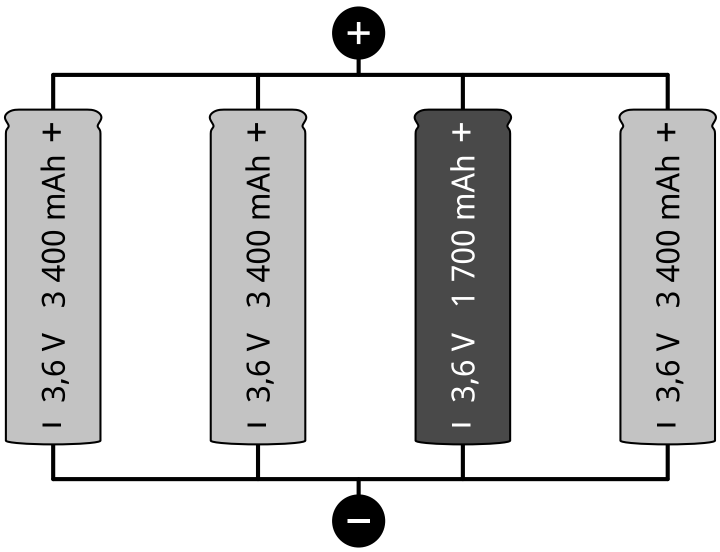


$$\frac{1}{r_T} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \frac{1}{r_4}$$

$$= \frac{1}{0{,}125} + \frac{1}{0{,}125} + \frac{1}{0{,}125} + \frac{1}{0{,}125}$$

$$= 0{,}031\ \Omega$$ **(2)**

18. Refer to the battery back illustrated below. How would the output of the battery pack be influenced if one of the cells is faulty?



The battery pack will still supply 3,6 V, but the total current supply will be less. **(2)**

TOTAL: 55

Module 3

Basic electronic components and semiconductors

After students have completed this module, they should be able to:

- recognise basic electronic components within the given range;
- indicate the rating of the components according to their physical sizes;
- classify the components in the range according to their functions;
- describe the basic functions and operation of the components;
- demonstrate an understanding of a resistor as a component in terms of:
  - its composition
  - the various types
  - its tolerance (indicated value vs. measured value)
  - colour codes (four- and five-band resistors) used
  - its power vs. its size
  - measuring its value
  - calculating its value;
- explain potentiometers in terms of their:
  - construction
  - functional operation
  - symbols;
- differentiate between a rheostat and a potentiometer in terms of their:
  - construction
  - functional operation
  - symbols;
- describe the properties of semiconductors;
- distinguish between intrinsic and extrinsic semiconductors;
- explain N- and P-type semiconductors by referring to their atomic structure;
- explain the meaning of majority and minority charge carriers;
- explain the formation of P- and N-type junctions (PN-junction);
- explain the formation of the depletion layer in a PN-junction;
- explain how voltage is applied across a PN-junction;
- explain the limitation in the operating conditions of a PN-junction;
- draw the characteristic curve of a typical diode;
- explain the basic operation of Zener and light-emitting diodes;
- describe the functions and applications of diodes;
- indicate the rating of the components by means of the physical marking on them;
- use diode specification sheets;

>>

>>

- explain the operation of half-wave and full-wave rectifier circuits, including filter circuits;
- explain what a transistor is;
- explain the basic purpose of a transistor within an electronic circuit;
- differentiate between two main types of bipolar transistors;
- incorporate a transistor/transistors in a basic electronic circuit;
- explain what an integrated circuit is;
- list the advantages and disadvantages of integrated circuits;
- classify integrated circuits according to their function;
- discuss the relationship between the concepts of a transducer and a sensor;
- explain the purpose of sensors and transducers as part of electric circuits and designs;
- name simple, non-electrical examples of instruments that measure the physical conditions in the range;
- explain the limitations of using sensors and transducers;
- list examples of transducers that sense the physical conditions in the range;
- classify the listed transducers according to their functions;
- describe the function of the listed transducers; and
- describe the construction and basic operation of the listed transducers.

Introduction

It is exciting to see the current technological developments. The field of electronics is growing more powerful and becoming more versatile day by day. Just take the simple cell phone of five years ago and compare its functionality and computing power to what is available today; the comparison is staggering. The same can be said for a wide range of electronic applications in the industrial field. Robotics is one of the most exciting fields of development, as are programmable logic control and variable speed drives, to name but a few. We really live in an exciting world.

However, to understand and work in this field, one must be able to identify, rate and explain the function of the basic components. Together, these components perform from the simplest to the most complex functions. This module introduces some of the basic components.

Activity 3.1

SB page 60

NOTE

This is only an example of the type of activity that can be done. Feel free to design one that suits your students.

WORKSHEET

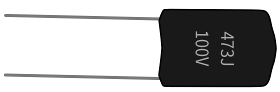
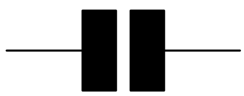
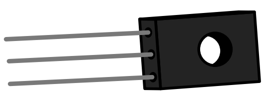
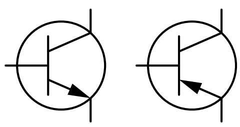
Identifying electrical components and providing circuit symbols

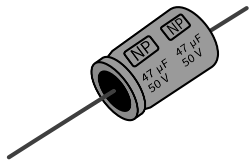
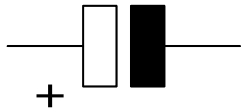
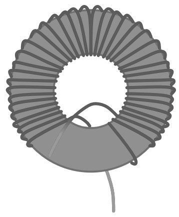
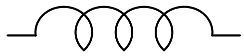
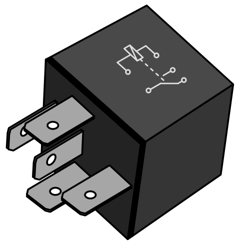
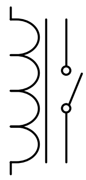
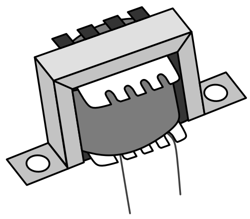
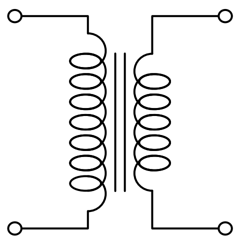
Name: ______________________________ **Date:** ________________

Class: ______________________________ **TOTAL: 25**

Instructions:

- Set out a variety of components for students to identify. Label the components 1 to 7.
- After allowing them time to view the components, hand out the worksheet for completion.

NAME OF COMPONENT	CIRCUIT SYMBOL
1. 1.1  Capacitor	
1.2  Transistor	
1.3  Resistor	

1.4  Capacitor (polarised)	
1.5  Inductor	 or 
1.6  Relay	
1.7  Transformer	

2. State the function(s) of each of the following components:

2.1 Capacitor

Stores an electrical charge temporarily so that it can be used again at a later stage

2.2 Transistor

Either acts as switches or amplifies small currents (signals)

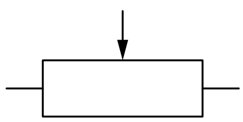
2.3 Transformer

Steps up or steps down voltage and current

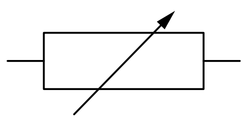
Activity 3.2

SB page 75

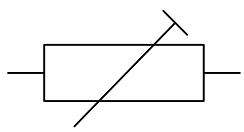
1. Name THREE types of variable resistors and draw the IEC symbol for each one.



Potentiometer



Rheostat



Pre-set resistor

2. **Capacitors are divided into two categories. Name the TWO categories.**

   Polarised and unpolarised

3. **What is meant by the *rating* of components?**

   The maximum voltage across it and the current flowing through the component without breaking down the integrity of the component; usually expressed in watt

4. **How does an inductor store its energy?**

   Through a magnetic field that surrounds the component while current flows

5. **Explain how a potentiometer works.**

   It consists of a resistance track with connections at both ends (points A and C) and a wiper (point B) that moves along the track as you turn the dial. The track is usually circular, but straight-track versions, usually called sliders, are also available. The sliding contact is used to vary the resistance offered by the potentiometer. The full resistance of the potentiometer lies across A and C.

   The resistance between A and B (or B and C) changes as the slider moves along the resistive element.

6. **Name THREE materials used for manufacturing fixed resistors.**

   Carbon composition; wire wound and metal film

7. **Write down the colour code for the following four-band resistors:**

   7.1 1 kΩ 2%

   Brown, black, red, red

   7.2 150 Ω 5%

   Brown, green, brown, gold

   7.3 47 kΩ 10%

   Yellow, violet, orange, silver

8. **Write down the value of a five-band resistor if the colour codes are as follows:**

   8.1 Yellow, brown, black, brown, red

   4 100 Ω 2% = 4,1 kΩ 2%

   8.2 Red, red, black, orange, gold

   220 000 Ω 5% = 220 kΩ 5%

9. **A multimeter is used to measure the value of an unknown resistor (the colour codes have been wiped off). Explain the steps you would follow to measure the value of the resistor.**

   - Insert the black lead into the common socket (COM) of the multimeter.
   - Insert the red into the socket marked V Ω.
   - Connect the leads across the resistor being tested.
   - Turn the dial of the meter to the ohm scale (Ω) and choose the position that gives you the best reading.

10. A 9-V battery is connected to a transistor radio with a resistance of 4 500 Ω. Calculate the current that the radio would draw from the battery.

$I = \frac{V}{R} = \frac{9}{4\,500} = 2\text{ mA}$

11. An electric motor draws 2,5 A and it has a resistance value of 96 Ω. Calculate the voltage connected to the motor.

$V = I \times R = 2{,}5 \times 96 = 240\text{ V}$

12. Explain the difference between a *potentiometer* and a *rheostat*.

There is no difference in the construction of these components. How the three terminals are used makes them different. When all the terminals are used, it is called a potentiometer. If only one of the end terminals and the wiper is used, it is called a rheostat.

Practical activity 3.1

SB page 94

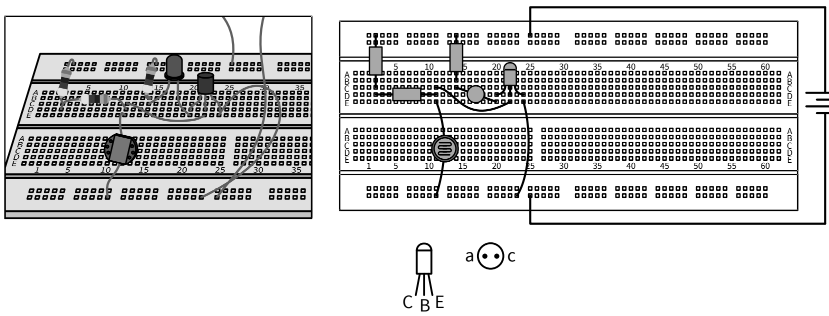
Lamp-control circuit using an LDR

Objective:
To investigate the effect of light intensity on the operation of the circuit

Material and equipment:
- Breadboard or logic trainer
- Digital multimeter
- 9-V battery or 9-V DC power supply
- All components indicated in circuit diagram in Figure 3.40
- Connecting cables or wires

Instructions:
1. Build the circuit illustrated in Figure 3.40 on the breadboard and connect it to the 9-volt DC supply (there is no AC input signal).

   Possible layout for the breadboard circuit:



2. Shine a light onto the LDR.
3. Measure the DC voltage between the collector of the transistor and the negative rail (bottom line): V_{output} = . . . volts.
4. Measure the DC voltage between the base of the transistor and the negative rail (bottom line): V_{input} = . . . volts.
5. Now remove the light and cover the LDR to simulate dark conditions.
6. Repeat steps 3 and 4 and record the readings.
7. Write a conclusion by comparing the readings under “light” and “dark” conditions.

For the next section, be consistent to ensure accurate results. Start in dark conditions and then move the light closer to the LDR. For the sake of consistency, keep the light intensity the same and always move it towards the LDR from the same distance and position as well as at the same speed. As the light is moved towards the LDR, notice the distance at which the LED switches on.

8. Turn the variable resistor fully clockwise (maximum resistance). Now move the light closer and measure at what distance from the LDR the LED switches on.
   Distance = … mm
9. Turn the variable resistor to the middle position (half resistance) and repeat the action.
   Distance = … mm
10. Turn the variable resistor fully anticlockwise (minimum resistance) and repeat the action.
   Distance = … mm
11. Given the results, what is your conclusion?

Before the practical

- Students should prepare for the practical at home by going over the theory.
- Set out all the materials and equipment.
- Build the breadboard circuit to use as an example.

During the practical

- Supervise and assist students.

Following the activity

- Supervise the cleaning and storage of projects, materials and equipment.
- Mark the activity.

Memorandum

1. Check the breadboard circuit and all connections.

2. Make sure students use the correct technique.

3. The DC voltage between the collector of the transistor and the negative rail (bottom line):
   V_{output} (V_{ce}) = ±8,5 V to 9 V

4. The DC voltage between the base of the transistor and the negative rail (bottom line):
   $V_{input} = V_{be}$ should be less than 0,6 V ($V_{be} \leq 0,6$ V)

5. Make sure the conditions are suited to the experiment.

6. Recorded readings:
   V_{output} (V_{ce}) = ±1,2 V
   $V_{input} = V_{be}$ = ±7 V (depending on the setting of the variable resistor).

7. Conclusion:
   During the day/in light conditions the LDR will have a low resistance compared to R_1 and R_2. This results in a low voltage drop across the LDR. The LDR is in parallel to the base emitter, and the V_{be} will also be low (typically less than 0,6 V). When the V_{be} is less than 0,6 V, the transistor cannot switch on. It acts like an open switch, and the full supply voltage will be across the collector and emitter (V_{ce}).

   At night/in dark conditions the LDR will have a very high resistance compared to R_1 and R_2. This results in a high voltage drop across the LDR. The LDR is in parallel to the base emitter, and the V_{be} will also have a high voltage (typically more than 0,6 V). When the V_{be} is more than 0,6 V, the transistor switches on fully and acts like a closed switch. The voltage drop across the transistor (V_{ce}) comes from the two junctions between collector base and base emitter. Current can flow through the LED and the transistor, and the LED lights up.

NOTE

The results obtained here will vary drastically from one experiment to the next as the variables play an important role. These are the readings we obtained during our experiment.

8. Distance = 70 mm

9. Distance = 100 mm

10. Distance = 125 mm

11. Conclusion:
When the variable resistor is turned to maximum, it will have a higher voltage drop across it. This means the LDR will experience a smaller voltage drop and the change in voltage when the light appears will be less sudden. The LED will switch on when the light is much closer.

When the variable resistor is turned to the minimum, it will have a low (basically zero) voltage drop across it. This means the LDR will have a higher voltage drop and the change in voltage when the light appears will be more sudden. The LED will switch on when the light is much further away.

By adjusting the variable resistor, we can control whether the LED switches on as it gets dark (as sun dips over horizon) or when it is dark (sun has set a while ago).

Practical activity 3.2

SB page 99

Digital ICs

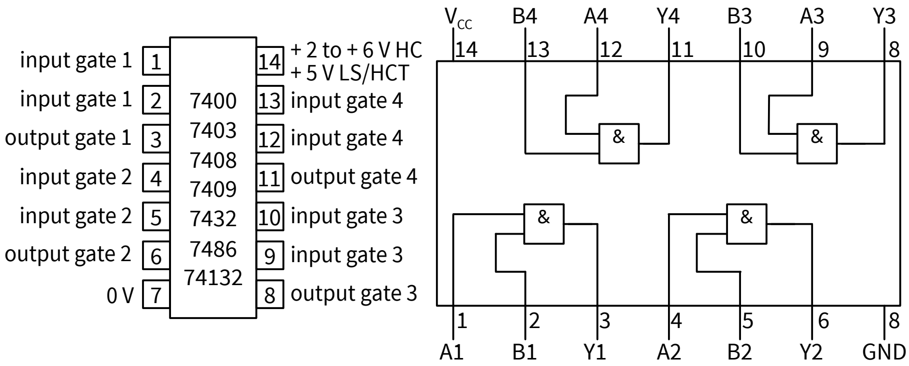
Objective:
To verify the outputs of a two-input AND gate using logic ICs as well as a multiple input AND gate

Logic gates are discussed in detail in Module 6.

Material and equipment:
- Digital trainer or equivalent trainer
- 7408-logic IC
- Single-strand hook-up wire
- Logic IC datasheet

IMPORTANT

- *Before starting with this activity, familiarise yourself with the pin connections of the ICs you are about to use. The pins are numbered anticlockwise around the IC (chip) starting at the notch or dot, as illustrated in Figure 3.42.*
- *The 7408 TTL IC series is designed to interpret inputs that are not connected as a high. This is also referred to as a floating high.*
- *The information on the next page will assist you during the practical.*



Instructions:

Part 1:

1. Insert the 7408-logic IC into the breadboard of the logic trainer. Consult the lecturer regarding the correct insertion of the IC.
2. Connect the supply and the ground connections to the respective inputs.

IMPORTANT

Do not connect the power unless the lecturer has checked the connections.

3. Considering the information regarding the IC given above, connect any one of the four logic gates and complete the truth table below.

INPUT A	INPUT B	OUTPUT
0	0	
0	1	
1	0	
1	1	

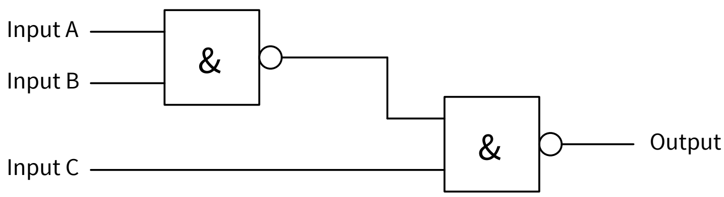
4. Why is the above gate also known as a *7408 Quad two-input AND gate*?
5. Draw a logic circuit of an AND gate.

Part 2:

6. Now that you have completed the above activity, use the same logic IC (7408) and construct the circuit below on your breadboard.
7. Remember to verify the pin connections by referring to the information given in the note above.

IMPORTANT

Do not connect the power unless the lecturer has checked the connections.



8. Draw up and complete the truth table that will represent the above circuit. (Tip: This will be a three-input truth table.)

Before the practical

- Explain the concept of logic gates, specifically the AND gate. Also explain what a truth table is and how it is used.
- Set out all the materials and equipment.
- Build the breadboard circuit to use as an example.

During the practical

- Supervise and assist students.

Following the activity

- Supervise the cleaning and storage of projects, materials and equipment.
- Mark the activity.

Memorandum

Part 1:

1 to 3:

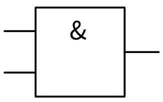
Check the breadboard circuit and all connections.

3.

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

4. It is called a 7408 Quad 2-input AND Gate because:
This type of IC is a 7408
There are 4 separate AND gates (QUAD)
Each gate has a maximum of two inputs

5.



Part 2:

6. and 7.

Check the breadboard circuit and all connections.

8.

INPUT A	INPUT B	INPUT C	OUTPUT
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Activity 3.3

SB page 101

1. **What is the basic difference between *intrinsic semiconductors* and *extrinsic semiconductors*?**

   An intrinsic semiconductor material is very pure chemically. It comprises only a single element. Germanium (Ge) and silicon (Si) are the most common types of intrinsic semiconductor elements.

   Extrinsic semiconductors are doped with specific impurities to modify their electrical properties. Usually, only one atom of 107 is replaced by a dopant atom in the doped semiconductor. An extrinsic semiconductor can be further classified into the N-type and the P-type.

2. **Explain the term *doping* as it relates to semiconductors.**

   The process of adding impurities or atoms to the pure semiconductor is called doping.

3. **Briefly explain how N-type materials are formed.**

   Impurity atoms with five valence electrons (called pentavalent impurities) produce N-type semiconductors by contributing extra electrons. The addition of pentavalent impurities, such as antimony, arsenic or phosphorous, contributes free electrons.

4. **Explain the operation of a diode with reference to forward and reverse biasing.**

   In forward biasing, the P-type material of the diode is connected to the positive terminal of the battery and the N-type to the negative terminal. During forward biasing, the positive terminal of the battery forces more holes into the P-region of the diode, while the negative terminal forces electrons into the N-region. The excess charge in P- and N-regions will apply pressure to the depletion region, making it shrink. As the voltage increases, the depletion region will become thinner and thinner and the diode will offer less and less resistance. Because the resistance decreases, the current will increase (though not proportional to the voltage).

   In reverse biasing, the P-type material is connected to the negative terminal of a battery and the N-type material to the positive terminal. In this condition, the holes in the P-type material are filled by electrons from the battery. In other words, the holes are sucked out of the diode. The electrons in the N-type material are sucked out of the diode by the positive terminal of the battery, depleting the diode of charge. The depletion region widens and occupies the entire diode. This increases the internal resistance of the diode and no current flows through it.

5. **Explain each of the following terms:**

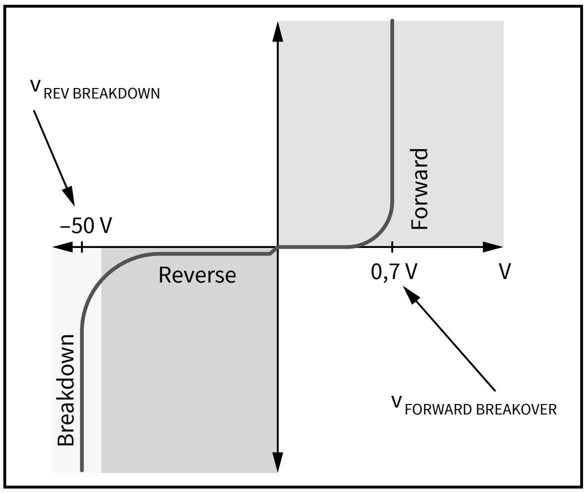
   5.1 Peak inverse voltage

   PIV – voltage at which a diode can start conducting when it is reverse biased

   5.2 Maximum forward current

   The maximum current that can flow through a forward-biased diode without damaging it

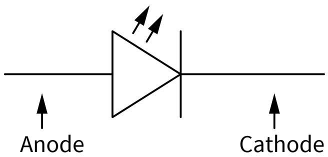
6. **Draw a neat characteristic current-versus-voltage curve for a diode.**



7. 7.1 **Explain what an *LED* is.**

An LED is a diode that is manufactured to emit light if current flows through it when it is forward biased.

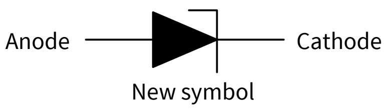
7.2 **Draw the IEC symbol used for an LED.**



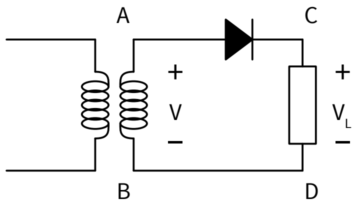
8. 8.1 **Explain what a *Zener diode* is.**

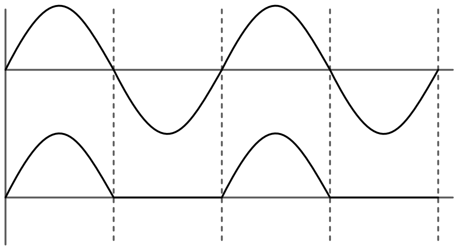
A Zener diode is a special kind of diode that will allow the forward and reverse flow of current when the voltage is above a certain value without damaging it. Unlike a normal diode, the Zener diode is specially manufactured or doped so that it can operate in reverse bias. The breakdown voltage is also known as the Zener voltage.

8.2 **Draw the IEC symbol used for a Zener diode.**



9. **Draw a neat circuit diagram for a half-wave rectifier. Show TWO cycles of the input wave forms as well as the output wave form.**





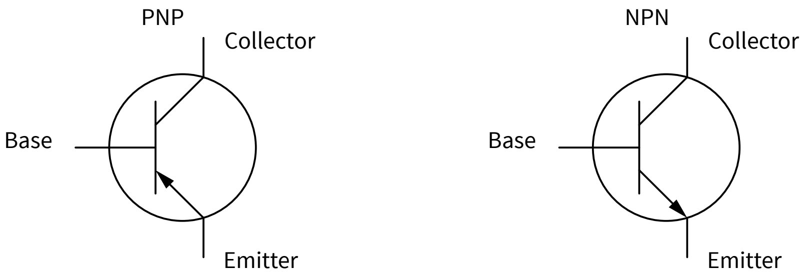
10. **Explain the operation of a bridge rectifier when it is operating in the positive half cycle.**

- Assume C is positive and D is negative.
- Current will flow from positive (C) through D_1, which is forward biased. (It cannot flow through D_4 or D_2, because they are reverse biased.)
- From D_1 it will flow to E, G, down through the load (R), through D_3 and back to negative (D).

11. **What is a *transistor*?**

A transistor is a solid-state electronic device used to amplify or control the flow of electricity in electronic equipment.

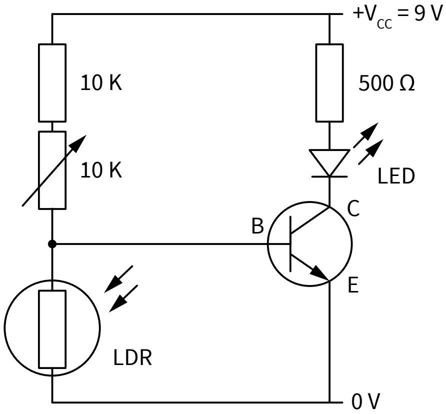
12. **Draw the IEC symbol to show the difference between an *NPN-transistor* and a *PNP-transistor*.**



13. **Name the THREE regions of operation of the transistor and state the base-emitter voltages required for the transistor to be in each of these regions.**

Transistor switched on fully (Current is maximum)	Saturation $V_{BE} \geq 1{,}2$ V
Transistor switching on more or less (One can control amount of current)	Active 0,6 V $\leq V_{BE} \leq$ 1,2 V
Transistor switched off (Current is zero)	Cut-off $V_{BE} \leq 0{,}6$ V

14. **A transistor is used as a switch in the electronic circuit shown below. The light-dependent resistor is the type that has a high resistance when it is dark and a low resistance when it is light. Explain the operation of the circuit.**

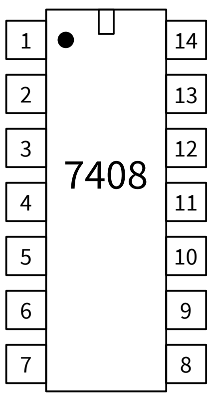


- The resistance of the LDR is low.
- This causes a low voltage drop across the LDR (below 0,6 V).
- A low voltage on the base of the transistor will prevent it from switching on.
- No current flows through the LED or the transistor (i.e. it acts like an open switch).
- The LED is off.
- The purpose of the variable resistor is to adjust the sensitivity of the circuit, in other words, how dark it must be before the LED switches on.

15. **Explain what an *integrated circuit* is.**

An integrated circuit is a set of electronic circuits on one small, flat piece of semiconductive material, usually silicon. It can also be described as a semiconductive wafer of silicon, measuring about 1 mm by 2 mm, onto which hundreds to thousands of tiny resistors, capacitors, diodes and transistors are mounted. Each layer is about 0,005 mm thick, depending on the size and type of IC. It can function as an amplifier, oscillator, timer, counter, computer memory, microcontroller or microprocessor.

16. **Copy the IC shown below and label all the terminals.**



17. Use a table to compare the advantages and the disadvantages of ICs.

ADVANTAGES	DISADVANTAGES
Very small and lightweight	High cost of the design process
Operating speeds are high	Fabrication of the required masks (the masters)
Relatively cheap because they are mass produced	High initial cost means ICs are only commercially viable when high production volumes are anticipated
Highly reliable	Cannot handle large currents or voltages
Use much less materials than individual transistors	Inductors and transformers cannot be incorporated into an IC
Consume much less power	Manufacturing of high-power ICs is not possible

18. Name TWO characteristics of a digital IC.

- Also called non-linear ICs
- Input and output voltages are limited to two possible levels, namely low or high
- Design requirements are not as high as those of linear ICs
- Commercially available as microprocessor chips, memory chips, analogue to digital chips, digitals to analogue chips, logic gates, flip-flops, counters, registers, etc.
- Far more transistors than linear ICs

Activity 3.4

SB page 105

1. Name THREE characteristics of a sensor.

A sensor can be defined as a device that detects a change in environmental conditions (e.g. light, sound and temperature) and presents the output in an easy-to-read format. For example, in a mercury thermometer, the mercury simply expands when the temperature rises to give the user a reading. There are no electrical inferences or changes. Sensors can sense a wide range of energy forms. A thermistor is an example of a sensor that converts a change that is non-electrical (heat) to a change in electrical quantity (resistance).

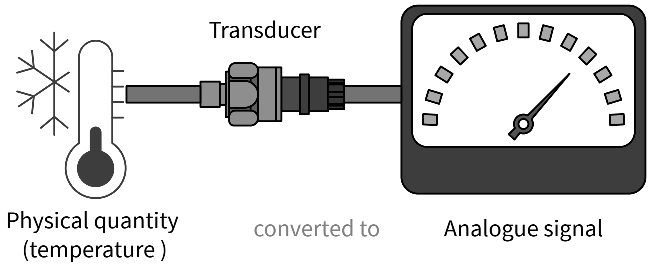
2. Give another name for a *transducer*.

Energy converter

3. Use a table to compare the key differences between a *sensor* and a *transducer*.

SENSOR	TRANSDUCER
Detects a change in a physical environment	Converts one form of energy into another
Cannot function as a transducer	Includes a sensor as a component
A component in itself	Comprises a sensor and a signal-conditioning circuit
Requires an additional circuit to process its output signal into a readable form	Does not require any processing circuit; its output is directly interfaced with a device or display
Output is analogue	Can generate analogue as well as digital output
Output cannot be directly applied to any other system	Output can be directly connected to another system
Does not require external power to operate	Passive transducer requires an external power source to operate

4. **Explain the energy conversions that is taking place in the system shown below.**

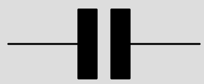
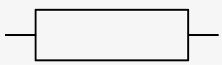
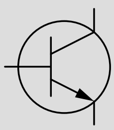
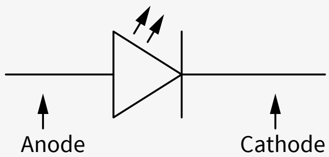
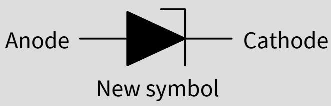
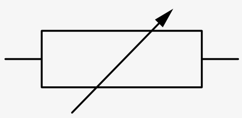


- The thermostat is the sensor. It senses any change in temperature.
- This change is converted to an electrical signal through the transducer.
- The electrical signal drives an output device, which could be either an analogue meter or a digital readout.

Summative assessment

SB page 113

1. **Complete the table below by providing the missing details. Write down only the question number and your answer.**

COMPONENT	SYMBOL	FUNCTION
E.g. Capacitor	**(a)** 	**(b)** *Stores an electrical charge temporarily*
Resistor	**1.1** 	**1.2** Controls how much current can flow in a circuit
1.3 Transistor		**1.4** Either acts as switches or amplifies small currents (signals)
LED	**1.5** 	**1.6** When current flows through forward-biased LED, it emits light
1.7		**1.8** Special type of diode designed to allow current to flow backward when a certain set reverse voltage, known as Zener voltage, is applied
Rheostat	1.9 	**1.10** An adjustable resistor; resistance can be changed without opening the circuit in which it is connected

(10 × 1)
(10)

2. **Provide the terms used for each of the following:**

   2.1 **The maximum voltage across it and the current flowing through the component without breaking down the integrity of the component; usually expressed in watts**

   Rating

2.2 A semiconductor that is very pure chemically, comprising only a single element

Intrinsic semiconductor

2.3 The process of adding impurities or atoms to a semiconductor to improve its electrical properties

Doping

2.4 A special component that will allow the forward and reverse flow of current when the voltage is above a certain value

Zener diode

2.5 A solid-state electronic device used to amplify or control the flow of electricity in electronic equipment

Transistor

2.6 An instrument used to measure electrical quantities such as current, voltage and resistance

Multimeter

2.7 An arrangement in a diode or other electrical device to allow a larger flow of current in a certain direction

Biasing

2.8 A set of electronic circuits on one small, flat piece of semiconductive material, usually silicon

Integrated circuit (IC)

2.9 A device that detects a change in environmental conditions (e.g. light, sound and temperature) and presents the output in an easy-to-read format

Sensor

2.10 A device that offers resistance based on the temperature around it

Thermistor **(10 × 1) (10)**

3. Why are coloured bands used on resistors?

The colours have specific values and indicate standard ratings of resistors. **(2)**

4. A resistor has the following colour code and ratings:
Brown, black, red and red; 1 kΩ; 2%
Calculate the range (the minimum and maximum values) we can expect the measured value to be.

1 kΩ 2%, A 2% tolerance means $1\,000\ \Omega \times 2\% = 1\,000 \times \frac{2}{100} = 20\ \Omega$

Minimum value = 1 000 – 20 = 980 Ω
Maximum value = 1 000 + 20 = 1020 Ω **(2)**

5. **Explain the difference between *N-type semiconductors* and *P-type semiconductors*.**

Impurity atoms with five valence electrons (called pentavalent impurities) produce N-type semiconductors by contributing extra electrons. The addition of pentavalent impurities, such as antimony, arsenic or phosphorous, contributes free electrons. This greatly increases the conductivity of the pure semiconductor. The overall electrical charge of this semiconductor is negative, hence the name N-type.

Impurity atoms with three valence electrons (called trivalent impurities) are used to produce P-type semiconductors. The addition of trivalent impurities, such as boron, aluminium or gallium, creates deficiencies of valence electrons, called holes. The overall electrical charge of this semiconductor is positive, hence the name P-type. **(4)**

6. **How would you determine the maximum regulated current for a specific Zener diode?**

Look up the code on the diode in the data sheet. **(2)**

7. **Name the THREE parts of a transistor.**

Base, collector and emitter **(3)**

8. **Name TWO types of ICs.**

Linear (analogue) and digital **(2)**

9. **Compare *sensors* and *transducers* given the following criteria. Redraw the table in your workbooks.**

CRITERIA	SENSOR	TRANSDUCER
Function	Detects a change in a physical environment	Converts one form of energy into another
In terms of needing additional circuits	Requires an additional circuit to process its output signal into a readable form	Does not require any processing circuit; its output is directly interfaced with a device or display
Type of output	Output is analogue	Can generate analogue as well as digital output

(6)

10. **What is the difference between an *active sensor* and a *passive sensor*?**

An active sensor does not need any external energy source and generates an electric signal directly in response to the external conditions. A passive sensor requires an external power called the excitation signal. **(2)**

11. **Explain what a *PIR sensor* is.**

PIR sensors use a pair of pyroelectric sensors to detect heat energy in the surrounding environment. The two sensors are located right next to each other. When the signal differential between the two sensors changes (e.g. if a person enters a room), the sensor will engage. **(2)**

TOTAL: 45

Module 4

Electrical components, symbols, circuit drawings, prototyping and design

After students have completed this module, they should be able to:

- list the symbols of electrical components;
- sketch the symbols of electrical components;
- interpret elementary circuits;
- sketch and label elementary circuits;
- build series and parallel circuits on breadboards based on a design;
- build series and parallel circuits on a Veroboard using basic soldering techniques;
- calculate the outcomes of the built circuits and verify the outcomes using the appropriate meters;
- mount listed components onto a breadboard and connect them to a circuit:
- describe different electric circuit combinations using various components and configurations, including:
  - series
  - parallel
  - series-parallel;
- explain the principles of operation of a combination of electrical components for a particular circuit with a purpose;
- sketch the circuit diagrams based on the information supplied, using IEC symbols;
- use appropriate formulae to calculate voltages, total resistance and currents in all the circuit branches as well as volt drops across resistors;
- apply Kirchhoff's laws in electric circuit calculations; and
- conduct practical circuit experiments to verify calculations.

Introduction

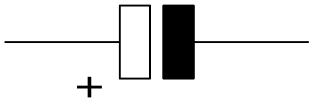
When students work in any electrical field, it is important that they know the different electrical components, their symbols and applications. (Note that some of these components were covered in Module 3.) They should also be able to read and understand simple circuit diagrams as well as use them to build circuits on a breadboard, Veroboard or PCBs. This module will help students come to grips with the abovementioned concepts. They will also learn how to do simple calculations based on different components connected in series or parallel.

Activity 4.1

SB page 120

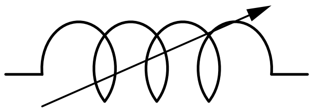
Sketch the symbol used to indicate each of the following electrical components:

1. **Polarised capacitor**

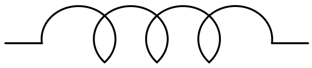


2. **Fixed resistor**

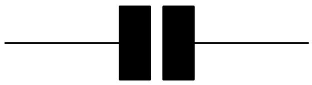
3. **Variable inductor**



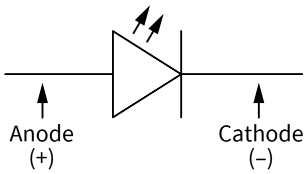
4. **Fixed inductor**



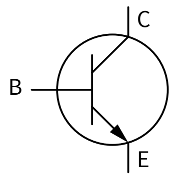
5. **Non-polarised capacitor**



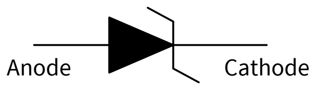
6. **LED**



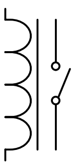
7. **NPN-transistor**



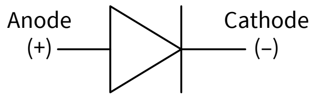
8. **Zener diode**



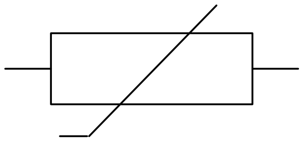
9. **Relay**



10. General purpose diode



11. Thermistor

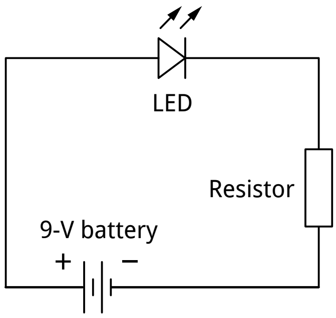


Activity 4.2

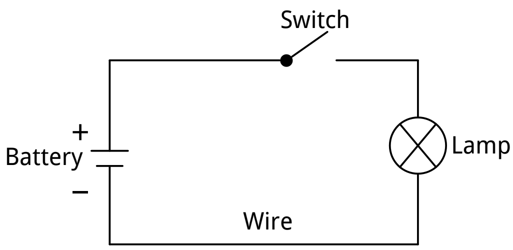
SB page 123

Make a neat, labelled drawing of each of the following circuits:

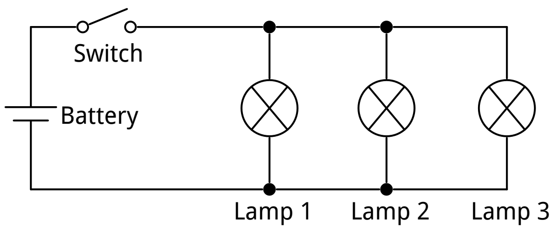
1. Battery, resistor and LED connected in series



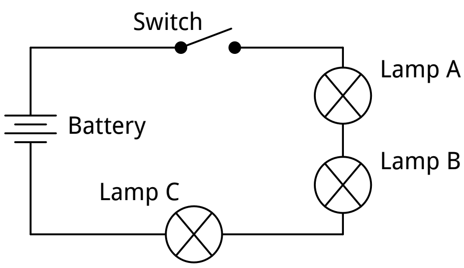
2. Open switch, battery and light bulb connected in series



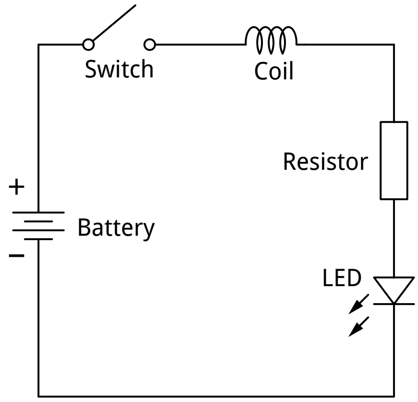
3. Three lamps connected in parallel to an open switch and a battery



4. Three lamps, open switch and battery connected in series



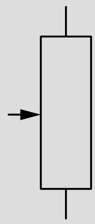
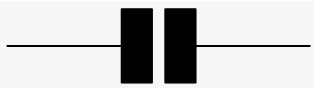
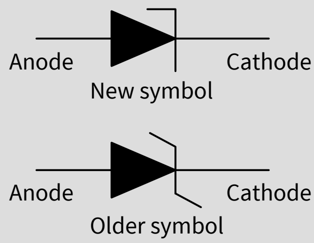
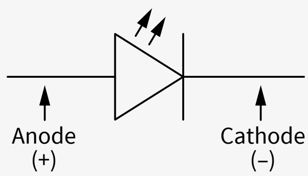
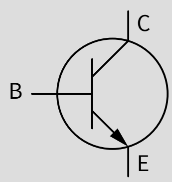
5. **Series circuit consisting of coil, LED, resistor, open switch and battery**

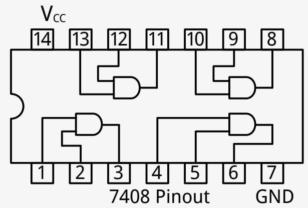
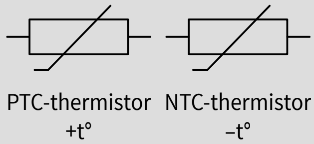


Summative assessment

SB page 160

1. **With reference to electrical components, complete the following table. Write down only the question number and the answer.**

COMPONENT NAME	COMPONENT SYMBOL
Potentiometer	**1.1** 
1.2 Non-polarised capacitor	
1.3 Zenner diode	
LED	**1.4** 
Transistor – NPN	**1.5** 

COMPONENT NAME	COMPONENT SYMBOL
1.6 Integrated circuit	
1.7 Sensor thermistor	

(7)

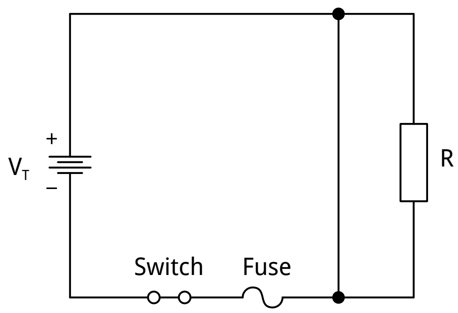
2. **Give a short description of an *electric circuit*.**

   An electric circuit can be described as a combination of various components connected together to form a continuous path allowing current to flow through it. **(2)**

3. **Name at least THREE different types of circuits that you will encounter in the electrical field.**

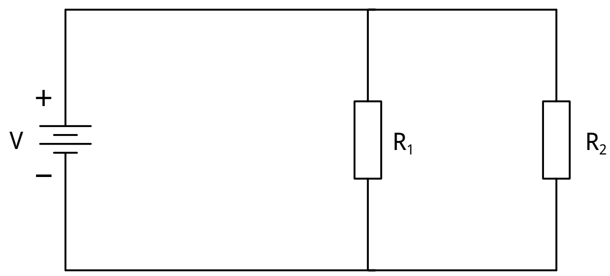
   Any THREE of the following:
   - Open circuits
   - Closed circuits
   - Short circuits
   - Series circuits
   - Parallel circuit **(3)**

4. **Identify the circuit shown in the figure below.** **(1)**

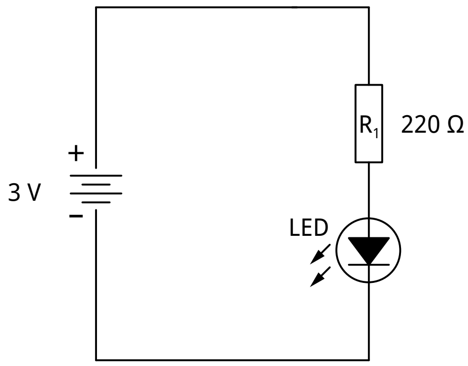


   Short circuit

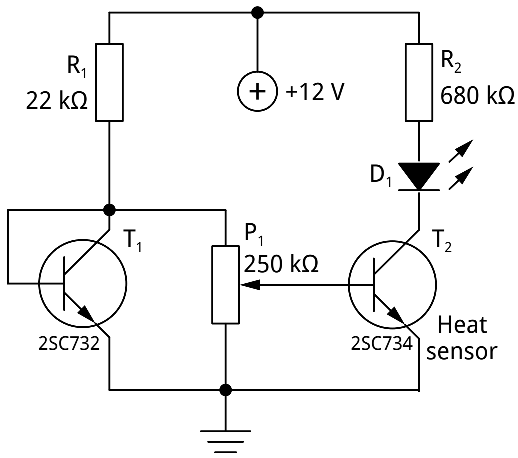
5. **By drawing a simple circuit, show how two resistors in parallel can be connected to a battery.** **(3)**



6. **Draw a circuit diagram consisting of a 3-V battery, a 220-Ω resistor and an LED connected in series.** **(3)**



7. **With reference to the circuit in the figure below, identify all the components used.**



- 2 × NPN-transistors
- 1 × potentiometer
- 1 × LED
- 2 × resistors **(4)**

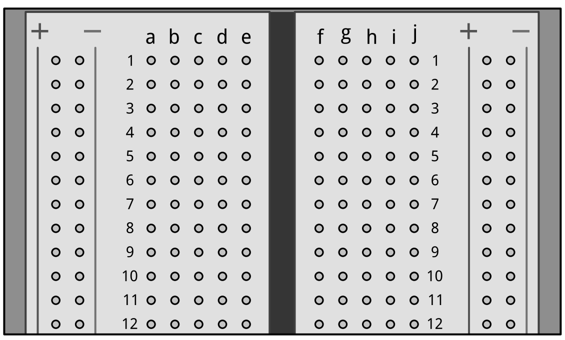
8. **8.1 Briefly explain what a *breadboard* is.**

   A breadboard is a thin plastic board used for constructing/building an experimental model of an electric circuit. **(2)**

   8.2 Explain why a breadboard is such a popular tool to use in electronics.

   It helps you to test a circuit before it is assembled. **(2)**

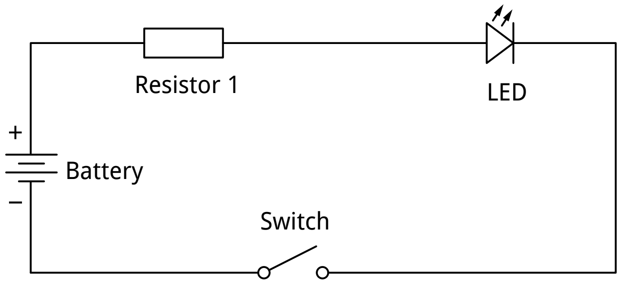
9. **Briefly explain the interconnections of the breadboard with reference to the figure below.**

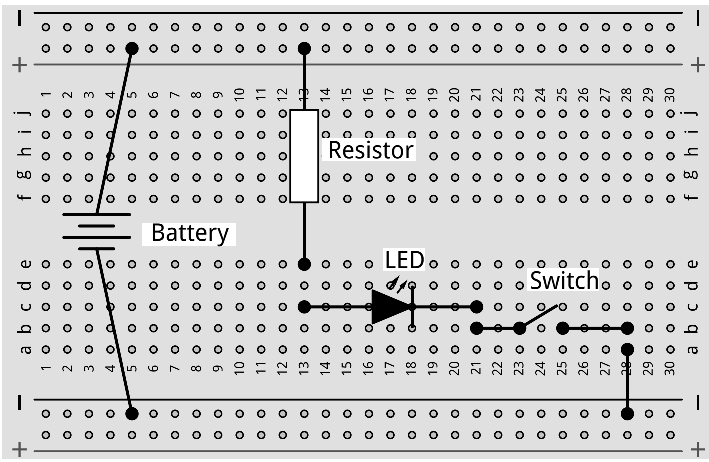


The holes represented by the positive or the negative sign are connected vertically down. Each line is connected individually. The holes next to the numbers 1, 2, 3, etc. are connected horizontally. Please note only a1, b1, c1, d1 and e1 are connected and f1, g1, h1, i1, and j1 are connected. **(4)**

10. Make a copy of a breadboard and paste it into your workbook. Show how you would connect the circuits below on the breadboard. Use symbols only.

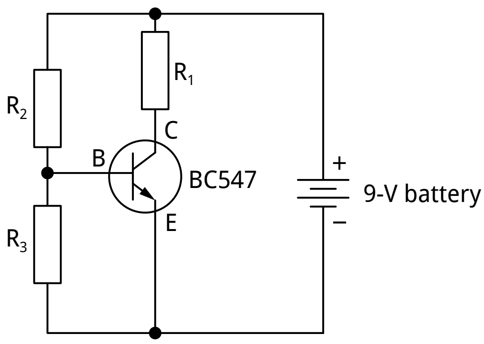
10.1

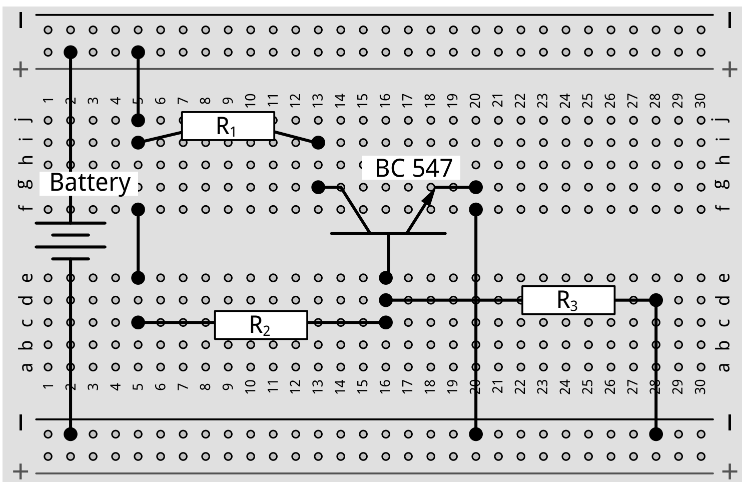




(5)

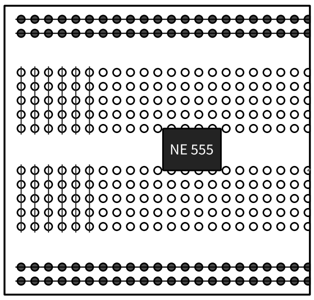
10.2





(6)

11. Describe why an IC has to be connected as indicated in the figure below.



ICs must always be connected across the centre open piece – one row of IC pins on one side and the other row on the other side. It will prevent the IC pins from shorting out. **(1)**

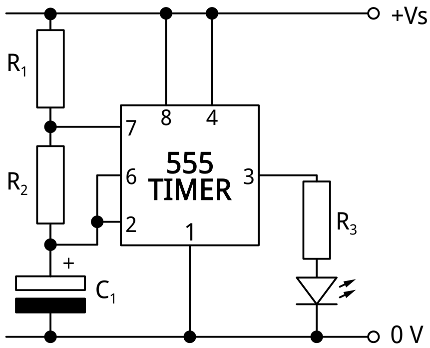
12. Explain what a *Veroboard* is.

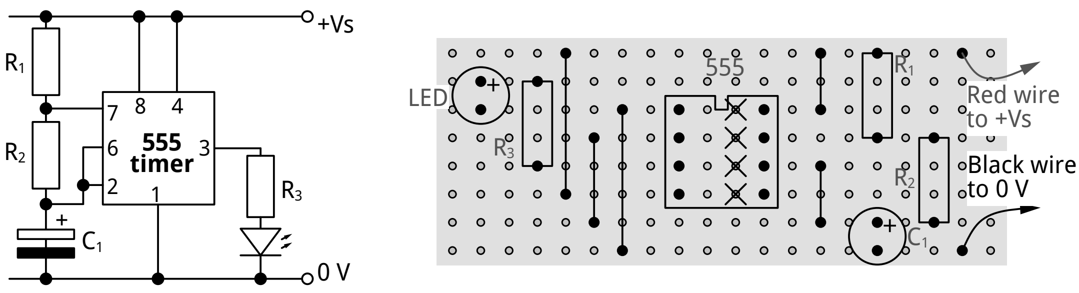
A Veroboard is a special type of insulated board. It has parallel strips of copper track on the underside and a clear, resin-bonded plastic or fibreglass board at the top. It is used for building simple circuits. **(3)**

13. Discuss the main difference between a *breadboard* and a *Veroboard*.

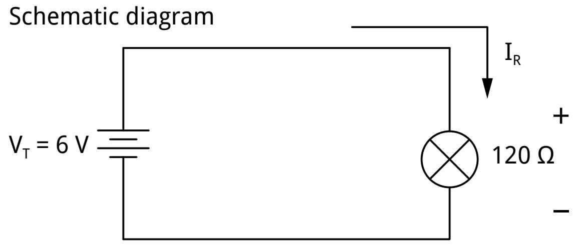
A breadboard is a non-permanent, solderless tool used for circuit construction.
A Veroboard is a permanent tool used for circuit building. Solder is used to fix the components to the board. **(4)**

14. Make a copy of a Veroboard and paste it into your workbook. Show how you would connect the circuit below on the Veroboard. Use symbols only. **(7)**





15. A flashlight uses a 6-V battery and its bulb has a resistance of 120 Ω. Calculate the amount of current that will be drawn from the batter when the flashlight is switched on.

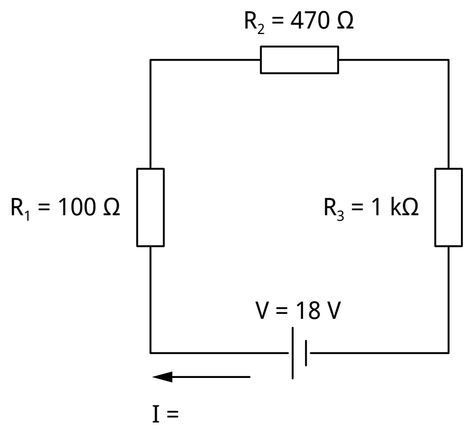


$I = \frac{V}{R}$

$= \frac{6}{120}$

$= 0{,}05$ A **(3)**

16. With reference to the figure below, calculate:



16.1 The total resistance of the circuit

$R_T = R_1 + R_2 + R_3$

$= 100 + 470 + 1\ 000$

$= 1\ 570\ \Omega$ or $1{,}57\ k\Omega$ **(3)**

16.2 The total current flowing through the circuit

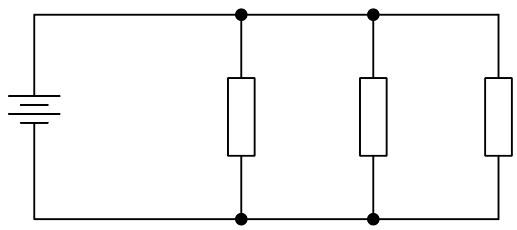
$I = \frac{V}{R}$

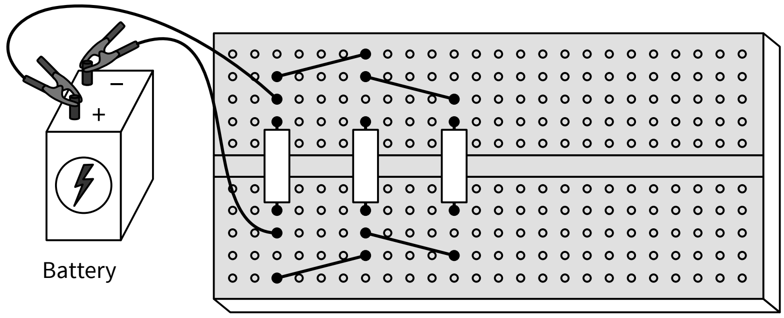
$= \frac{18}{1\ 570}$

$= 0{,}0115$ A or 11,5 mA **(3)**

17. Draw a simple breadboard in your workbook and construct the circuits represented by the diagrams below.

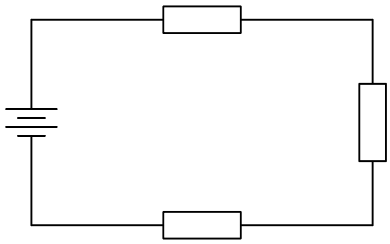
17.1

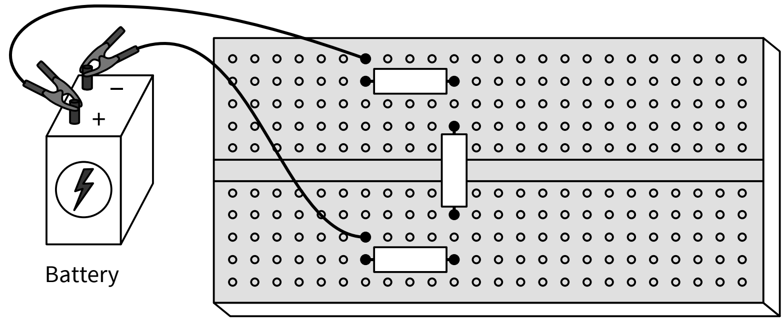




(4)

17.2





(4)

18. Calculate the total resistance of a circuit when three resistors are connected in parallel. The resistors have a value of 100 Ω each.

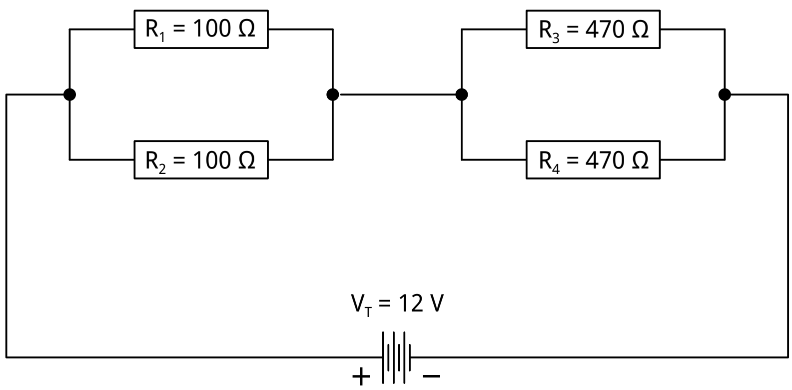
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{100} + \frac{1}{100} + \frac{1}{100}$$

$$= 0{,}03$$

$R_T = 33{,}33\ \Omega$ **(3)**

19. With reference to the circuit in the figure below, calculate the total resistance of the circuit.



$\frac{1}{R_{12}} = \frac{1}{R_1} + \frac{1}{R_2}$

$= \frac{1}{100} + \frac{1}{100}$

$R_{12} = 50\ \Omega$

and

$\frac{1}{R_{34}} = \frac{1}{R_3} + \frac{1}{R_4}$

$= \frac{1}{470} + \frac{1}{470}$

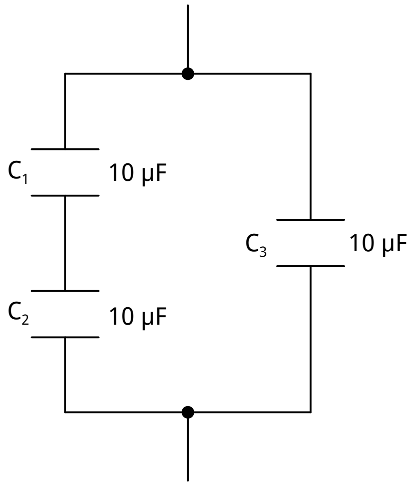
$R_{34} = 235\ \Omega$

So: $R_T = R_{12} + R_{34}$

$= 50 + 235$

$= 285\ \Omega$ **(9)**

20. Calculate the total capacitance of the circuit in the figure below.



$\frac{1}{C_{12}} = \frac{1}{C_1} + \frac{1}{C_2}$

$= \frac{1}{10} + \frac{1}{10}$

$C_{12} = 5\ \mu F$

So: $C_T = C_{12} + C_3$

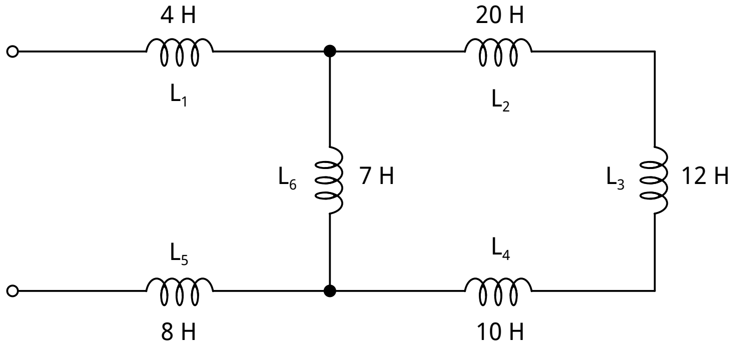
$= 5 + 10$

$= 15\ \mu F$ **(6)**

21. How will the total inductance be influenced if you connect inductors in parallel?

The total inductance will decrease and will always be less than the smallest inductor in the parallel combination. **(2)**

22. With reference to the figure below, calculate the total inductance of the circuit.



$L_{234} = L_2 + L_3 + L_4$

$= 20 + 12 + 10$

$= 42$ H

Then

$\frac{1}{L_{2346}} = \frac{1}{L_{234}} + \frac{1}{L_6}$

$= \frac{1}{42} + \frac{1}{7}$

$= 0,167$

$L_{2346} = 6$ H

and

$L_T = L_{2346} + L_1 + L_5$

$= 6 + 4 + 8$

$= 18$ H **(9)**

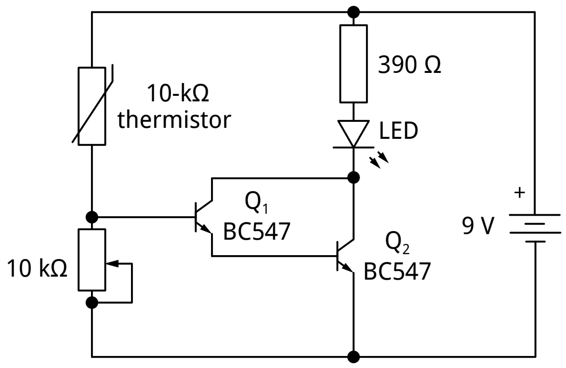
23. Complete the following table with reference to resistors, capacitors and inductors connected in series and in parallel.
Note: Give the formula for only two components.

ELEMENT	RESISTORS	CAPACITORS	INDUCTORS
Series	**23.1** $R_T = R_1 + R_2$		
Parallel		**23.2** $C_T = C_1 + C_2$	**23.3** $\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2}$

(3)

24. With reference to the circuits below, briefly explain the operation of each one.

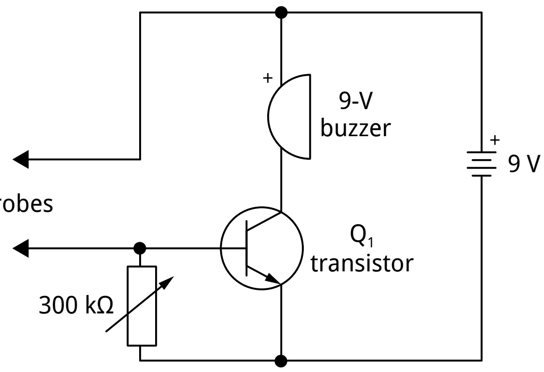
24.1



(6)

Temperature-activated switch: A thermistor is used to activate the switch in this circuit. Thermistors are activated by heat. As soon as the thermistor is heated to a certain point, its resistance decreases. This activates the two transistors, which allows current to flow through them, thereby lighting up the LED.

24.2



(6)

Water-level buzzer: A water-level buzzer is used to detect the water level in a container. The probes are placed into a container that is filled with water. As soon as the water touches the probe, the circuit is closed. The transistor will switch on and the buzzer will sound.

25. Will the total resistance of a circuit *increase* or *decrease* when a resistor is connected in series?

The resistance will increase. **(1)**

26. Three resistors of 5 Ω, 6 Ω and 13 Ω, respectively, are connected in series across a 12-volt supply. Calculate:

26.1 The total resistance of the circuit

$R_T = R_1 + R_2 + R_3$

$= 5 + 6 + 13$

$= 24\ \Omega$ **(3)**

26.2 The current drawn from the supply

$I = \frac{V_T}{R_T}$

$= \frac{12}{24}$

$I_T = 0{,}5$ A **(3)**

27. Three resistors of 4 Ω, 12 Ω and 15 Ω, respectively, are connected in series across a 24-V supply. Calculate:

27.1 The total resistance of the combination

$R_T = R_1 + R_2 + R_3$

$= 4 + 12 + 15$

$= 31\ \Omega$ **(3)**

27.2 The current flow through each resistor

$I = \frac{V_T}{R_T}$

$= \frac{24}{31}$

$= 0{,}774\ A$ **(3)**

27.3 The voltage drop across the 4-Ω resistor

$V_{4\Omega} = I_T \times R_1$

$= 0{,}774 \times 4$

$= 3{,}096\ V$ **(3)**

27.4 The voltage drop across the 15-Ω resistor

$V_{15\Omega} = I_T \times R_3$

$= 0{,}774 \times 15$

$= 11{,}61\ V$ **(3)**

28. Define ***Kirchhoff's voltage law*****.**

Kirchhoff's voltage law states that the sum of the voltage drops across the resistances of a closed circuit equals the total voltage applied to the circuit. **(3)**

29. What is remarkable about the current in a parallel circuit?

The total current equals the sum of all the currents flowing through each parallel branch of the circuit. **(2)**

30. Three resistors of 12 Ω, 8 Ω and 6 Ω, respectively, are connected in parallel across a 12-V supply. Calculate:

30.1 The total resistance of the combination

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

$= \frac{1}{12} + \frac{1}{8} + \frac{1}{6}$

$= 0{,}375$

$R_T = 2{,}667\ \Omega$ **(3)**

30.2 The current drawn from the supply

$I_T = \frac{V_T}{R_T}$

$= \frac{12}{2{,}667}$

$I_T = 4{,}499\ A$ **(3)**

30.3 The current flow through the 8-Ω resistor

$I_{R2} = \frac{V_T}{R_3}$

$= \frac{12}{8}$

$= 1{,}5\ A$ **(3)**

TOTAL: 160

Module 5

Electronic tools and equipment

After students have completed this module, they should be able to:

- use basic electronic tools and measuring equipment;
- explain the layout of a breadboard using an ohmmeter or continuity tester;
- demonstrate the use of a voltmeter, ammeter and ohmmeter;
- distinguish between analogue and digital measuring instruments;
- eliminate parallax error when reading analogue meters;
- list the advantages of digital meters compared to analogue meters;
- explain the operation of moving-iron and moving-coil instruments;
- list and describe, with examples, different electrical measuring and testing instruments used in practice;
- sketch and explain how measuring and testing instruments are inserted in circuits;
- list the precautions that should be taken when using measuring and testing instruments;
- sketch and explain the basic design and operating principles of an insulation-resistance tester;
- explain how the range of a voltmeter and ammeter can be increased;
- test specific components using appropriate equipment;
- test diodes and capacitors using a diode tester or ohmmeter; and
- look up semiconductor components in a technical manual.

Introduction

When they work in an electrical or electronic field, students will use instruments to test, calculate or measure the value of electrical quantities such as current, voltage, resistance and power. Students must be familiar with measurements and measuring instruments. *Measurement* refers to the unit value that is used to measure specific quantities. Measuring instruments can be used to measure or compare components as well as to check whether they are functioning properly. These instruments can also be used to verify calculations, as students learned in the previous module. A measuring instrument is often called a *meter*. Examples of electrical measuring instruments include the ammeter, voltmeter, ohmmeter and wattmeter. Students are already familiar with the multimeter, a very versatile measuring instrument. The breadboard, introduced previously, is an example of a tool that is used in the construction and testing of circuits.

Activity 5.1

SB page 192

1. 1.1 **What does *prototyping a circuit* mean?**

   It is the building of a circuit on a breadboard to see if it works according to requirements.

   1.2 **Why is prototyping done on a breadboard?**

   The electronic breadboard allows you to build circuits of any size without having to solder a single component into place. It also allows you to experiment with the circuit and easily replace a component with one of a different value. You can test how changing components would affect the circuit.

2. **What should you bear in mind when building a breadboard?**

   - Take care not to short-circuit components when you insert them into the breadboard.
   - ICs are always mounted across the middle ridge of the breadboard.
   - Other components should never be connected on tracks that are joined.
   - Use thin, insulated wires to connect components on one track to components on another track. (Hint: Only strip about 3 mm of insulation off the end of the wires to be used.)
   - Ensure that you insert the wire (component lead) into the right hole.
   - Ensure that component leads that are not insulated do not touch the board and cause short circuits.
   - Always use the outer track at the top from your perspective as the positive supply and the bottom track as the negative. This avoids confusion in the building process.

3. **Redraw the table below in your workbook and complete it by providing the missing details (name of the meter, its purpose and the symbol used to indicate it).**

METER	PURPOSE	SYMBOL
Ammeter	Measuring a wide range of DC or AC values; only a small portion of the current is directed through the meter; unit of measurement is ampere (A)	A
Voltmeter	**Measuring the potential difference or voltage between two points in an electric circuit. It is measured in volt (V)**	V
Ohmmeter	Measuring electrical resistance in an electrical circuit; unit of measurement is ohm (Ω)	Ω

4. **Explain the difference between a *digital multimeter* and an *analogue multimeter*.**

   Digital: Meter has a numeric display that is easy to read
   Analogue: Meter uses the deflection of a pointer on a scale to indicate the measurement

5. **How can parallax errors be avoided?**

   When taking the reading, position your eyes directly above the needle on the meter's display.

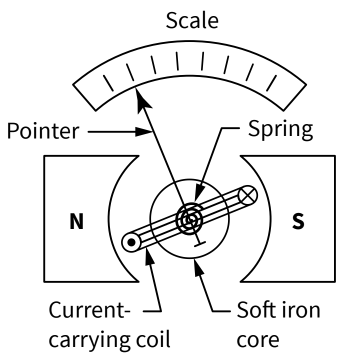
6. **Name THREE advantages of a digital multimeter when compared to an analogue meter.**

   Any THREE of the following:
   - Digital display is easy to read – LCD display
   - Reduced risk of errors when taking a reading from the display
   - Not influenced by magnetic fields
   - More robust (no moving needles that can be damaged)
   - No need for zeroing a needle for accurate readings
   - The display has no moving parts that may wear
   - Some models have auto-ranging, which means you select a setting (voltage or current) and it automatically selects the best scale
   - The auto-polarity function can prevent problems when the meter is connected to a test circuit
   - Can be used for testing continuity, capacitors, diodes and transistors; more advanced meters can also measure frequency
   - Cause less loading effect
   - Minimum/Maximum/Average readings can be displayed on the digital meter

7. **Name TWO types of moving-iron core meters.**

   Attraction type and repulsion type

8. **Name the parts numbered 1 to 4 in the sketch below.**



9. **Explain the basic operation of the moving-coil meter.**

   When a current flows through the coil, a magnetic field is set up around the windings of the coil. A force is exerted between the electromagnetic field of the coil and the permanent magnetic field of the permanent magnet. The larger the current through the coil, the stronger the electromagnetic field will be. Consequently, the larger deflecting torque will cause the needle to move further across the screen.

10. **List the precautions that should be taken when you connect a voltmeter into a circuit.**

- It must be connected in parallel.
- The power to the circuit must be on.
- Start at the highest scale and work your way down.

11. **Which meter gives a reading in hertz?**

Frequency meter

12. **What does the kilowatt-hour meter measure?**

Electrical energy consumed over a period

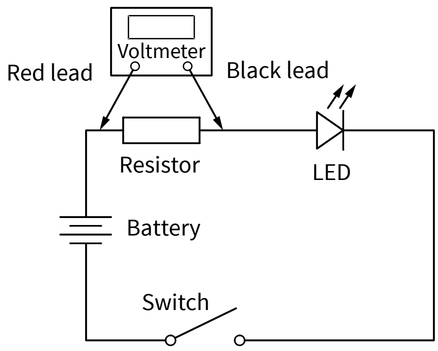
13. **Which meter measures the consumption of power at any given time?**

Wattmeter

14. **Which meter requires the circuit to be broken (disconnected) before the meter can be inserted in series?**

Ammeter

15. **Draw a neat, labelled sketch to show how a voltmeter is connected into a circuit to measure the voltage drop across a component.**



16. **Name THREE precautions that should be taken when you use a clamp-on meter.**

- Never clamp the live wire between the teeth of the clamps.
- Never clamp both the live and the neutral wire at the same time.
- Keep the meter away from other current-carrying wires while measurements are taken.

17. **Why can a multimeter not be used to do an electrical test on a new household installation of an electric motor?**

A multimeter only tests at 9 V (its internal battery). A Megger/insulation tester tests at double the supply voltage.

18. **Why should electrical installations be tested at double their supply voltage?**

If the tests are acceptable at a high voltage, then it will definitely be acceptable at the normal operating voltage. However, if the installation is tested at 9 V, it may very well not be acceptable at a the normal (higher) operating voltage.

19. Name the THREE tests that should be carried out on any new electrical installation by using an insulation tester.

- Continuity test
- Insulation resistance between windings
- Insulation resistance between windings and earth

20. What is the minimum accepted resistance reading when performing the insulation test between conductors and earth?

1 MΩ

21. Name THREE meters that require the supply to the circuit to be switched off before any tests are performed or measurements taken.

- Megger or insulation-resistance tester
- Continuity tester
- Ohmmeter

22. Name the precautions that should be taken when you use an insulation-resistance meter.

- The supply to the circuit must be switched off.
- Test to see whether the battery is good.
- Select the correct scale (insulation – megaohm; continuity – ohm)
- Take care to select correct measuring points (they differ depending on the test)

23. Name the FOUR basic parts of the Megger and briefly explain the function of each.

- Control and deflection coil: These are normally mounted at a right angle to each other and connected parallel to the generator. The polarities are such that the torque produced by them is in opposite directions.
- Permanent magnet: These permanent magnets with north and south poles produce a magnetic effect for the deflection of the pointer.
- Pointer and scale: A pointer is attached to the coils and the end of the pointer floats on a scale with a range from zero to infinity. The unit is ohms.
- DC generator or battery connection: The testing voltage is supplied by a hand-operated DC generator for a manually operated tester. A set of batteries and an electronic voltage charger is used for an automatic tester.

24. What is the resistor that is connected in series to a meter to extend its scale called?

Multiplier resistor

25. What is a *shunt resistor*?

A resistor that is connected in parallel with the meter, allowing any excess current to flow along that parallel path. This allows measurements of higher currents that would have been beyond the capability of the meter.

Practical activity 5.1

SB page 194

Using a multimeter to test and measure a resistor

You will need

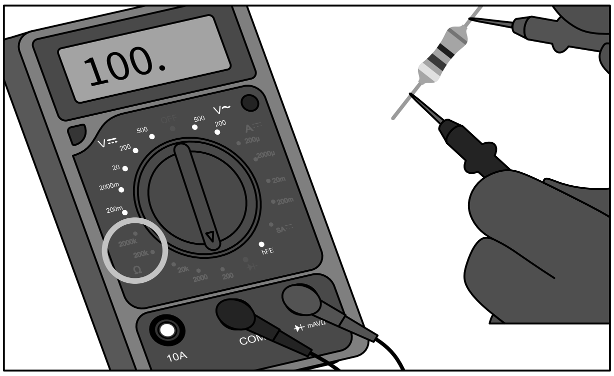
- Digital multimeter
- 1 × fixed resistor (1 000 Ω or 1 kΩ)

NOTE

For correct measurements, make sure the leads of the multimeter are connected correctly: the black lead must be connected to the COM terminal, and the red lead to the V/mA/Ω terminal.

Instructions

1. Turn on the multimeter and select the ohm setting, as shown below. Select the 2 000 Ω range if you are not using an auto-range multimeter.



2. Read the resistor value – it will be printed on the resistor. Smaller resistors may have their value indicated by colour-coded brands. Record it in the table provided.
3. Connect the two leads of the multimeter to the two legs of the resistor, as shown in the figure above. (Resistors have no polarity, so it does not matter which lead is connected to which resistor leg.)
4. Take the reading and record it in the table provided.

GIVEN VALUE	1 000 Ω
MEASURED VALUE	990 Ω

Conclusion

The reading on the multimeter will be very close to the given value of 1 000 Ω. The measured and given values differ because of the tolerance of the resistor.

Practical activity 5.2

SB page 198

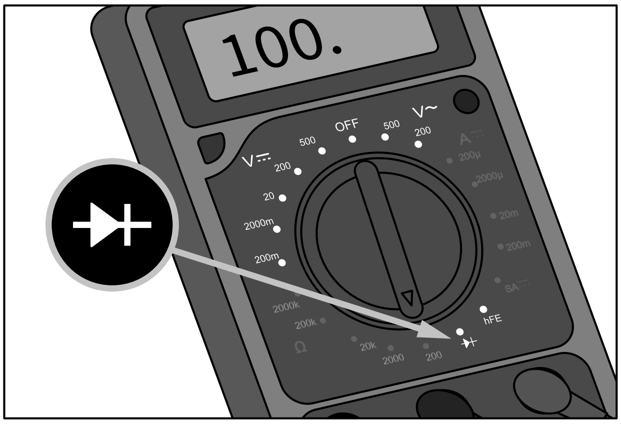
Using a multimeter to test and measure a diode

You will need

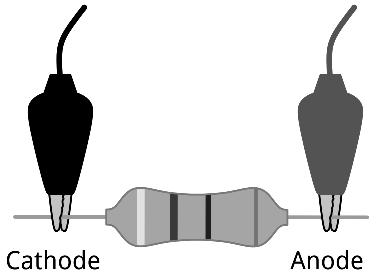
- Digital multimeter
- 1 × diode (1N4007)

Instructions

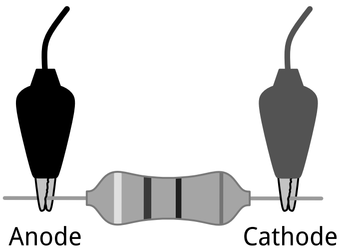
1. Turn on the multimeter and select the diode test mode/setting (diode symbol/'diode check'/2 mA), as indicated in Figure D.

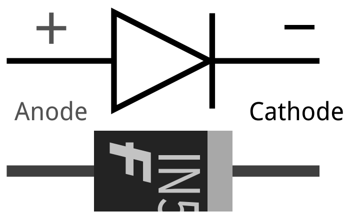


2. Connect the red lead (+) of the multimeter to the anode of the diode, and the black lead (–) to the cathode. This puts the current in the forward direction, thus the diode is forward biased.



3. Take the reading and record it in the table provided. (It should be between 0,5 and 0,8 V if it is a 'healthy' diode. Any other reading indicates that the diode is not working properly.)
4. Now connect the red lead to the cathode and the black lead to the anode. (This is the reverse biased reading.)





Results

CONNECTION OF LEADS	READING ON MULTIMETER
Anode (red lead)	0,7 V (forward biased)
Cathode (black lead)	
Cathode (red lead)	0 V (reverse biased)
Anode (black lead)	

Conclusion

If the diode is in good working order, the forward biased reading should be about 0,5 and 0,8 V and the reverse biased reading about 0 V.

Practical activity 5.3

SB page 201

Using a multimeter to test and measure an LED

You will need

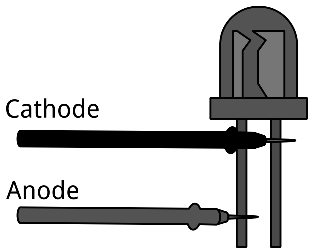
- Digital multimeter
- 1 × red LED

NOTE

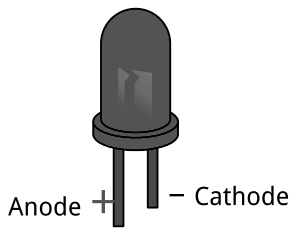
A diode and an LED are tested in the same way.

Instructions

1. Turn on the multimeter and select the diode test mode/setting (diode symbol/'diode check'/2 mA), as indicated in Figure D.
2. Determine the anode and cathode side of the LED. (The long leg is usually the anode (+) and the short one the cathode (–).) Connect the red lead of the multimeter to the anode of the LED, and the black lead to the cathode, as illustrated in Figure G.



3. Check the LED. Indicate whether it is emitting or not in the table provided.
4. Take the multimeter reading and record it in the table provided.
5. Now connect the red lead to the cathode and the black lead to the anode.
6. Repeat steps 3 and 4.



Results

CONNECTION OF LEADS	READING ON MULTIMETER
Anode (red lead) Cathode (black lead)	1,8 V (forward biased) – LED will be on
Cathode (red lead) Anode (black lead)	0 V (reverse biased) – LED will be off

Conclusion

If the LED is in good working order, the forward biased reading will be about 1,8 V and the reverse biased reading will be 0 V. The LED will only light up if the red lead is connected to the anode and the black to the cathode, i.e. when it is forward biased.

Activity 5.2

SB page 205

1. **Why must the supply to the circuit be switched off before components are tested or measurements taken?**

   To ensure your safety (prevent electric shocks) and the safety of the meter (prevent it from blowing up)

2. **Why is it important to connect the red lead to the positive and the black lead to the negative of the capacitor when testing it?**

   Capacitors are polarised

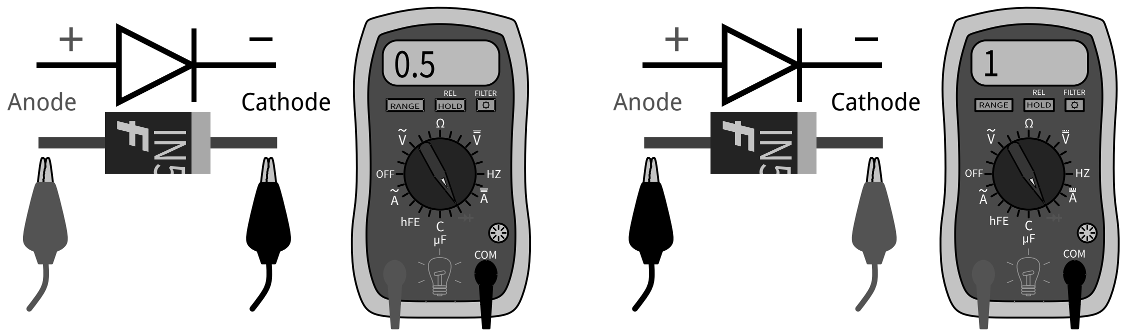
3. **Give another name for a *coil*.**

   An inductor

4. **Complete the table below by stating the multimeter setting that should be used as well as the expected reading when each of the following components is measured.**

COMPONENT	SCALE (SELECTOR SWITCH)	EXPECTED READING
Resistor	Highest ohm scale	Change the selector switch until a suitable reading appears on the display (typically between 0,5 and 0,8)
Capacitor	2-kΩ scale	• Digital multimeter will briefly show a reading. • It will immediately return to the 1 or the OL reading
Inductor	Low ohm scale	Reading between 1 Ω and 11 Ω
Diode	Diode setting	• Diode must be tested both in forward and in reverse bias • Any reading in forward bias • No reading in reverse bias
LED	Diode setting	• LED must be tested both in forward and in reverse bias • Any reading in forward bias or it might shine dimly • No reading in reverse bias (no light)

5. **Draw a neat, labelled sketch to show the TWO ways in which a diode should be connected when it is tested.**



Forward biased

Reverse biased

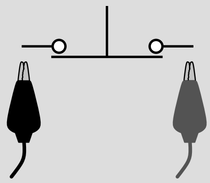
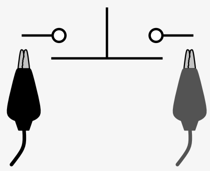
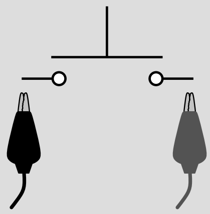
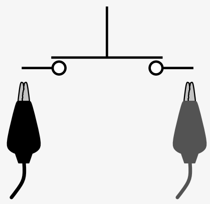
6. Name TWO types of push buttons and briefly explain the difference between them.

Normally open and normally closed

The normally open push button switch is an open switch. When it is pressed, the contacts close. The moment you lift your finger off the button, a spring returns the switch contacts to the open position.

The normally closed push button switch is a closed switch. When it is pressed, the switch contacts open. The moment you lift your finger off the button a spring returns the switch contacts to the closed position.

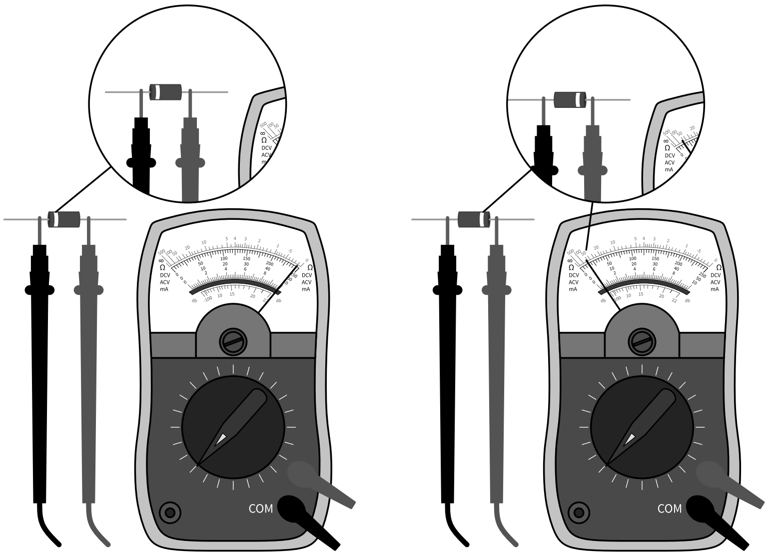
7. The table below shows push button switches connected to a multimeter. Identify the type of switch and state the expected reading on the multimeter.

SWITCH TESTED	TYPE OF SWITCH (STATE IF PRESSED OR NOT)	EXPECTED READING
	• Normally closed • Not pressed	• Closed circuit • Low ohm reading
	• Normally closed • Pressed	• Open circuit • Reading of 1 or OL
	• Normally open • Not pressed	• Open circuit • Reading of 1 or OL
	Normally open pressed	• Closed circuit • Low ohm reading

8. A multimeter is set to the ohm scale to measure a diode. Give a detailed description of how the meter should be set up.

- Switch off the supply to the circuit.
- Isolate the diode from the circuit (disconnect one terminal).
- Insert the red lead into the VΩ (red) socket and the black lead into the COM (black) socket.
- Select the low ohm scale.
- Connect leads across the diode in forward bias/reverse bias.

9. The sketch below shows an analogue meter that is used to measure a diode. Interpret each of the meter readings and state whether the diode is functional or not.



Sketch on the left: The diode is connected in forward bias (red lead to anode and black lead to cathode). The meter needle deflects, showing the diode is conducting in forward bias.

Sketch on right: The diode is connected in reverse bias (red lead to cathode and black lead to anode). The meter needle does not deflect, showing the diode is not conducting in reverse bias.

Conclusion: The diode is fully functional. It only conducts in one direction.

10. An analogue multimeter set to the ohm scale is used to test a functioning capacitor. Explain how the meter reading should be interpreted to establish whether the capacitor is indeed functional.

Functional capacitor: The needle will show low resistance and then gradually increase towards infinity.

Summative assessment

SB page 215

1. Why is the breadboard a popular option when prototyping a circuit? **(2)**

- No soldering required
- Easy to change components to see the effect on the operation of the circuit

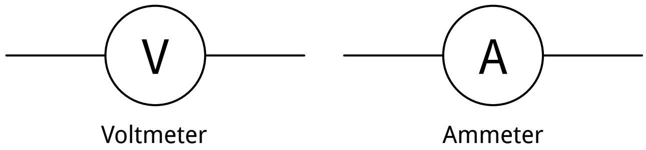
2. When inserting components into a breadboard, special care must be taken that their respective wires to not touch.
Explain why this would be a problem. **(2)**

Components' leads are always bare (not insulated). Should they touch, it will cause a short circuit between them and the circuit will not operate as desired.

3. What is a *multimeter*? **(2)**

It is a measuring instrument that can perform various functions, e.g. measuring voltage, current and resistance and testing diodes. It eliminates the need to carry various instruments that can only measure one thing.

4. **Make neat drawings of the symbols used for a *voltmeter* and an *ammeter*.** **(2)**



5. **When you look at a circuit diagram, how would you tell whether an analogue or a digital meter is used?** **(2)**

You cannot tell. The same symbol is used for both, as both perform the same function.

6. **6.1 What is meant by *parallax error*?** **(1)**

This error occurs due to the wrong positioning of the eyes while taking a reading on an analogue meter./ It occurs when your eyes are not directly above the meter's display.

6.2 How does it affect the operation of the circuit and your subsequent conclusions? **(2)**

It will not affect the operation of the circuit, but your conclusions might be wrong, as they would be based on inaccurate readings.

7. **Name FOUR advantages of a digital meter compared to an analogue meter.** **(4)**

Any FOUR of the following:
- Digital display is easy to read – LCD display
- Reduced risk of errors when taking a reading from the display
- Not influenced by magnetic fields
- More robust (no moving needles that can be damaged)
- No need for zeroing a needle for accurate readings
- The display has no moving parts that may wear
- Some models have auto-ranging, which means you select a setting (voltage or current) and it automatically selects the best scale
- The auto-polarity function can prevent problems when the meter is connected to a test circuit
- Can be used for testing continuity, capacitors, diodes and transistors; more advanced meters can also measure frequency
- Cause less loading effect
- Minimum/Maximum/Average readings can be displayed on the digital meter

8. **Identify the instrument described below.**

> A measuring instrument in which current or voltage is determined by the force on a small coil pivoted between the poles of a magnet with curved poles, giving a radial magnetic field

(1)

Moving-coil meter

9. **What is the disadvantage of a multimeter used as an ammeter compared to a clamp-on meter?** **(2)**

When using a multimeter, the circuit must be broken. For this to happen, the supply needs to switched off. Extra care must be taken to select the correct scale.

10. 10.1 State the purpose of a frequency meter. **(1)**

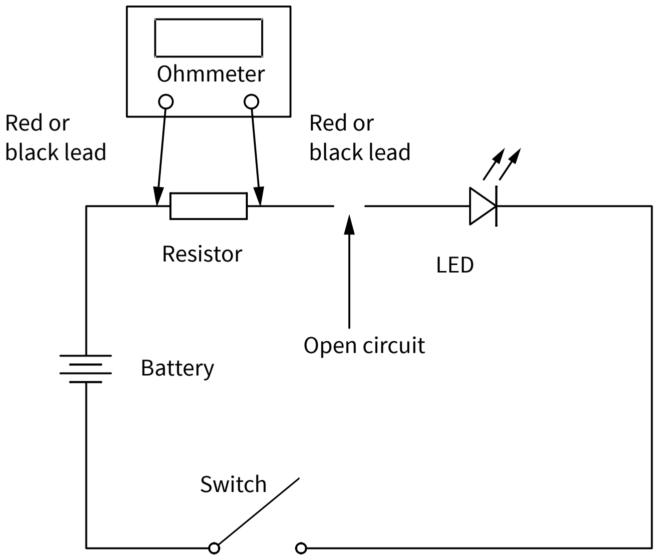
Measuring or monitoring the frequency of virtually anything that uses electricity

10.2 State THREE applications for a frequency meter. **(3)**

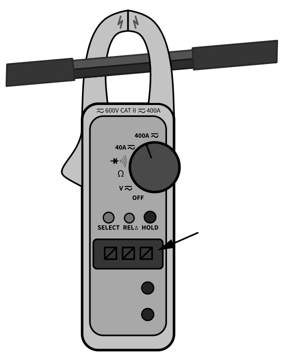
Any THREE applications

- Electric motors
- Pool pumps
- Generators
- Electric vehicles
- Power-generation plants
- Distribution grids
- Invertor-monitoring circuits

11. A 9-V battery is connected to an LED protected by a resistor to prevent it from blowing. With the aid of a neat sketch, show how a voltmeter is connected into the circuit to measure the voltage across the resistor. **(4)**



12. A clamp-on meter is used to measure the current flow supplied to a single-phase load. Why would the clamp-on meter below give a zero reading? **(2)**



- Both the live and the neutral wires run through the clamp-on meter.
- The current in the two wires will be equal, but it will flow in opposite directions. (Live will flow to the load and neutral will flow back from the load.)
- The two opposing magnetic fields around the wires will cancel each other out.

13. Name the THREE tests that are usually performed using an insulation-resistance tester. **(3)**

- Continuity test
- Insulation resistance between windings
- Insulation resistance between windings and earth

14. Give another name for an *insulation-resistance tester*. **(1)**

Megger

15. What is the minimum acceptable reading for an insulation test? **(1)**

1 MΩ

16. Name the precautions that need to be taken when connecting a digital voltmeter into a circuit to measure the volts. **(3)**

- The supply to the circuit must be switched on.
- The meter must be connected in parallel.
- Start at the highest scale and work your way down until a suitable reading is gained.

17. How can the scale of the ammeter be extended? **(1)**

By connecting a resistor in parallel to the meter

18. Why must a resistor be connected in series to the meter to extend the voltage scale? **(3)**

- A resistor in series will cause an additional voltage drop in the circuit.
- A portion of the voltage will be dropped across the meter and the rest across the resistor.
- This allows measurements of higher voltages that would have been beyond the capability of the meter.

19. Why must a diode be tested by connecting it to the meter in both directions? **(2)**

- It needs to be tested in both forward and reverse bias.
- If the diode fails either of the two tests, it is not functional.

20. Why does an LED glow dimly when tested with a multimeter? **(2)**

When tested in forward bias, the battery of the multimeter is sufficient to allow enough current to flow through the LED so that it glows.

21. Explain what sort of reading you would expect on the display of an analogue multimeter when you are testing a capacitor that is fully functional. **(2)**

The needle will show low resistance and then gradually increase towards infinity

22. Name TWO details that a data sheet will provide concerning a component. **(2)**

Any TWO of the following:

- What the component does
- Product image
- Symbol
- Shape
- Physical dimensions
- Lead placement
- Temperature ranges
- Voltage ranges
- Current ranges
- Power ranges
- Frequency ranges
- Gain (as in amplification)
- Stability
- Electrostatic-discharge warning
- Curves for determining how parameters interact with each other

TOTAL: 50

Module 6

Digital systems and principles

After students have completed this module, they should be able to:

- distinguish between analogue and digital signals;
- list the advantages of digital systems over analogue systems;
- explain how voltage levels are used to represent bits;
- explain how voltage levels are interpreted by a digital circuit;
- explain the concepts of positive and negative logic in terms of voltage levels;
- describe the general characteristic of a pulse;
- explain how a digital wave form carries binary information;
- define the term *Boolean logic*;
- explain how Boolean logic relates to electronic and digital computing and problems;
- discuss how Boolean logic provides a system of logical operations;
- express a Boolean algebra statement;
- describe the operation of NOT, AND and OR logic gates and their respective truth tables;
- discuss the term *logic diagram* and its purpose;
- discuss the term *logical gate* as it relates to NOT, AND and OR gates;
- draw a simple logic diagram incorporating different gates based on a scenario or expression;
- correctly use IEC symbols to represent logic gates;
- use each logic gate in a simple application; and
- interpret basic data sheet information.

Introduction

Understanding basic digital and logic concepts is important, because they are the building blocks used in all digital equipment such as computers, banking and communication systems, cars and many other everyday applications. Knowing digital systems allows us to better understand the working principles of such systems and it will also help us in repairing digital devices. The world around us is rapidly moving towards using only digital information, so we need to know what it involves and how to use it to our advantage. This module covers the basics of digital systems to lay the foundation for further studies in this field.

Activity 6.1

SB page 222

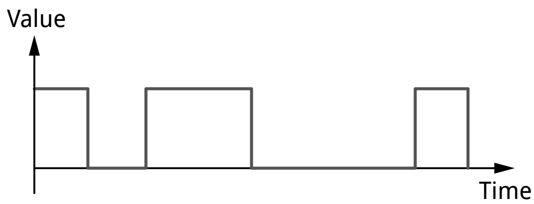
1. **Define the term *analogue signal*.**

   An analogue signal is made up of a continuous range of values, where each point can have a slightly different value as time varies. The signal is represented as a continually varying wave.

2. **With reference to digital logic, what voltage level does *logic 1* represent?**

   A logic 1 represents 5 V.

3. **Make a neat, labelled drawing of a simple digital signal.**



Digital signal

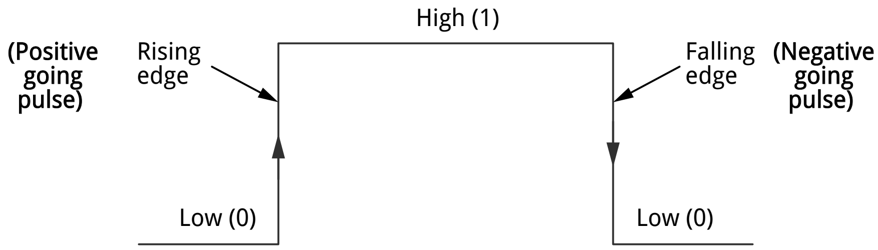
4. **Name THREE advantages of using digital signals.**

   Any THREE of the following
   - Signals are discrete and contain only distinct values (0 or 1)
   - Fault finding is much easier
   - Less noise interference
   - Represented by a square wave
   - Amount of power used by digital signals is less
   - Great volumes of information can be stored or transmitted

5. **Define *positive logic*.**

   Positive logic is where a high voltage level represents a logic 1 and a low voltage level represents a logic 0.

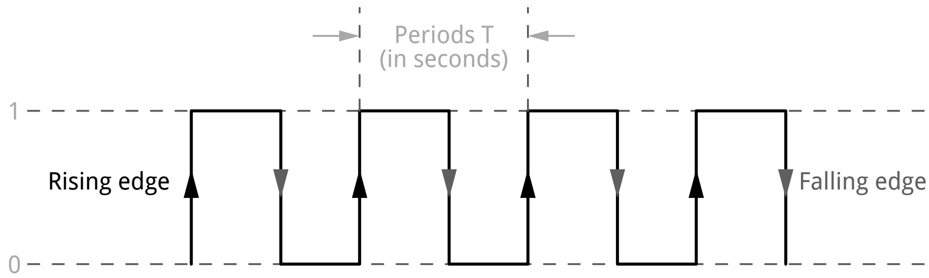
6. **Make a neat drawing of a digital pulse, indicating the positive and negative going pulses.**



7. **What do you understand by the term *clock pulse*?**

   It is a continuous train of square wave pulses used to coordinate and control the internal operation/actions of digital circuits.

8. **Make a neat drawing of a train of clock pulses.**



9. **Explain the term *timing diagram*.**

   A timing diagram is a special form of a sequence diagram explaining the sequence of events with reference to the inputs and outputs with every clock pulse (leading or falling edge).

Activity 6.2

SB page 225

1. **Define the term *Boolean logic*.**

   Boolean logic is a form of algebra where all values are either true or false; or a system of algebraic notation used to represent logical propositions by means of the binary digits 0 (false) and 1 (true).

2. **Who can be described as the father of Boolean logic?**

   George Boole, an English mathematician of the 19th century

3. **Name the TWO values used in Boolean logic.**

   The two possible values are 0 or 1.

4. **Name the THREE basic logic operations.**

   Logic addition (OR), logic multiplication (AND) and logic inversion (NOT)

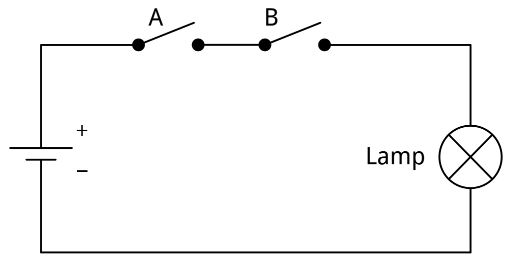
5. **Write down the Boolean statement for the *OR function*.**

   Q = A + B

Activity 6.3

SB page 238

1. **Draw a switching circuit and truth table for a two-input AND gate.**

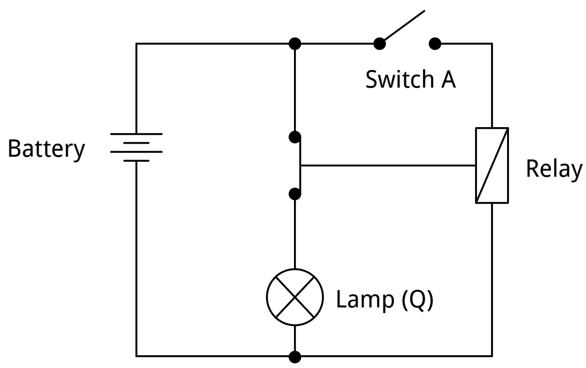


SWITCH A (INPUT)	SWITCH B (INPUT)	LAMP (OUTPUT)
0	**0**	0
0	**1**	0
1	**0**	0
1	**1**	1

2. **Complete the truth table for the OR gate given below.**

SWITCH A (INPUT)	SWITCH B (INPUT)	LAMP (OUTPUT)
0	**0**	0
0	**1**	1
1	**0**	1
1	**1**	1

3. **Which logic gate does the following switching circuit represent?**



NOT gate

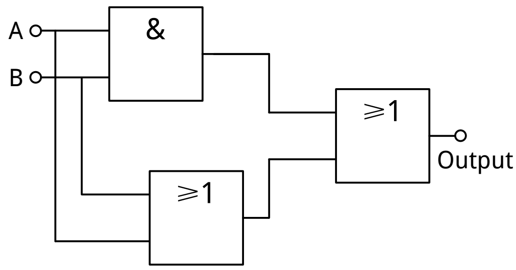
4. **Draw the truth table for the logic gate represented in QUESTION 3.**

SWITCH A (INPUT)	LAMP (OUTPUT Q)
0	1
1	0

5. **Define the term *truth table*.**

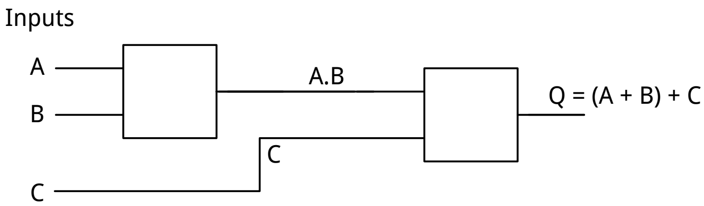
   A truth table is a mathematical table that shows all the possible outcomes from all the scenarios considered at the input.

6. **Name all the logic gates used in the combination circuit below.**

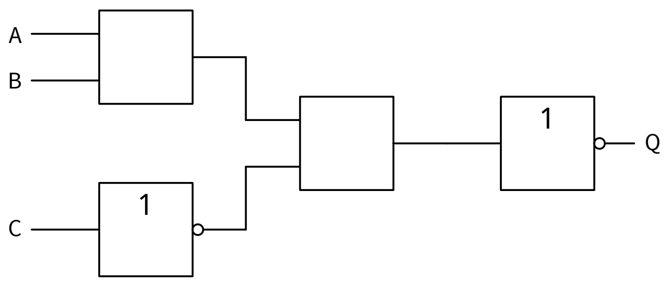


- 1 × NOT gate
- 1 × AND gate
- 1 × OR gate

7. **Draw the logic diagram for the following Boolean expression:**
   Q = (A + B) + C.



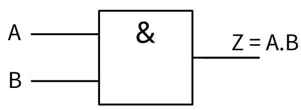
8. **Draw the logic diagram for the following Boolean expression:**
   $(\overline{A + B + \overline{C}}) = Q$



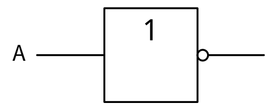
9. **What does the abbreviation *IEC* stand for?**

   International Electrotechnical Commission

10. **Draw the IEC symbol and output expression for a two-input AND gate.**



11. **What logic gate does the following IEC symbol represent?**



The NOT gate

12. **Write down the output Boolean expression for a two-input OR gate.**

Q = A + B

13. **Give TWO types of details you will be able to find of a logic gate data sheet.**

Information such as pin layout, truth table, internal construction of the gate, supply voltage, input voltage, switching characteristics, high-level output currents

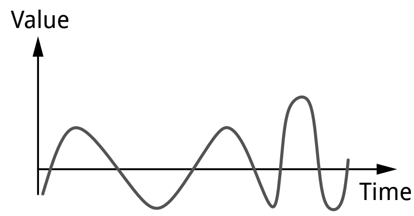
Summative assessment

SB page 239

1. **Explain the difference between** ***analogue signals*** **and** ***digital signals*****.**

Analogue signals have a gradual change from one level to the next, whereas digital signals vary only between two logic states. **(4)**

2. **Make a neat, labelled drawing of an analogue signal.** **(3)**



Analogue signal

3. **Digital signals can be represented by TWO logic levels. Name them.**

Logic 1 and logic 0 **(2)**

4. **Which voltage levels do the logic levels in QUESTION 3 represent?**

Logic 1 = 5 V and logic 0 = 0 V **(2)**

5. **In table form, compare *digital signals* with *analogue signals*.**

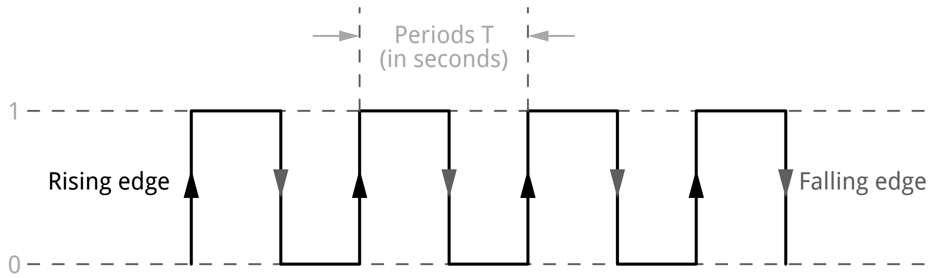
DIGITAL SYSTEMS	ANALOGUE SYSTEMS
Signals are discrete and contain only distinct values (0 or 1)	Signals are continuous and vary in strength (amplitude) or frequency (waves per unit time)
Fault finding is much easier	Fault finding is more difficult
Less interference due to noise	More noise interference
Represented by a square wave	Represented by a sine wave or a continually varying wave
Uses less power	Uses more power
Great volumes of information can be stored or transmitted	Less information can be stored or transmitted

(12)

6. **What type of logic does the following voltages represent?**
5 V = 1 and 0 V = 0

Positive logic **(1)**

7. **Make a neat, labelled drawing of a train of clock pulses.** **(3)**



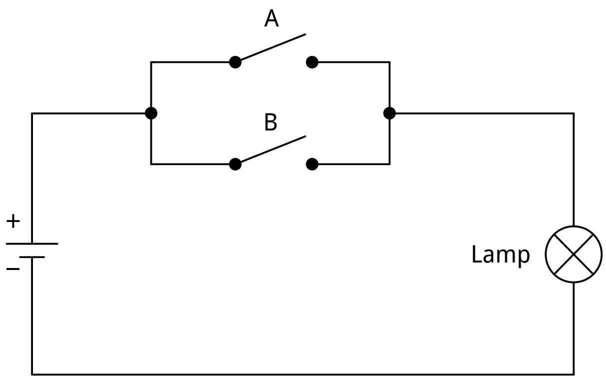
8. **Define the term *Boolean logic*.**

Boolean logic can be defined as a form of algebra where all values are either true or false. **(2)**

9. **Write down the Boolean statement for the OR and AND functions.**

A + B = Q (OR function) and A.B = Q (AND function) **(2)**

10. **Draw a neat switching diagram for the OR gate.** **(4)**



11. What logic gate does the following truth table represent?

SWITCH A (INPUT)	SWITCH B (INPUT)	LAMP (OUTPUT)
0	0	0
0	1	1
1	0	1
1	1	1

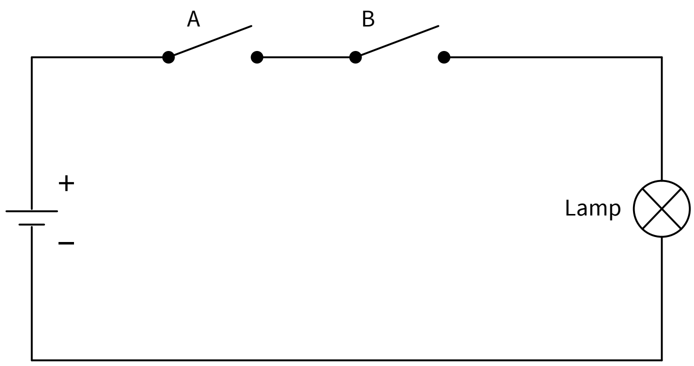
OR gate **(1)**

12. Complete the truth table for the AND gate.

SWITCH A (INPUT)	SWITCH B (INPUT)	LAMP (OUTPUT)
0	0	0
0	1	0
1	0	0
1	1	1

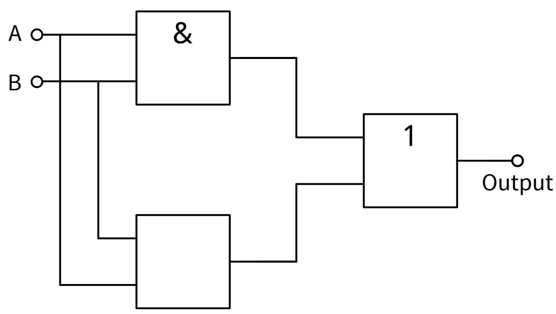
(4)

13. Which logic gate does the following switching circuit represent?



AND gate **(1)**

14. Name all the logic gates used in the combination circuit below.

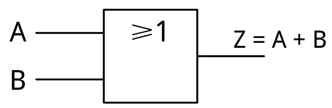


1 × AND gate and 2 x OR gates **(2)**

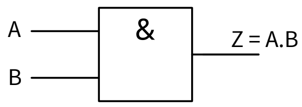
15. What does the abbreviation *IEC* stand for?

International Electrotechnical Commission **(1)**

16. Draw the IEC symbol with output expression for a two-input OR gate. **(4)**



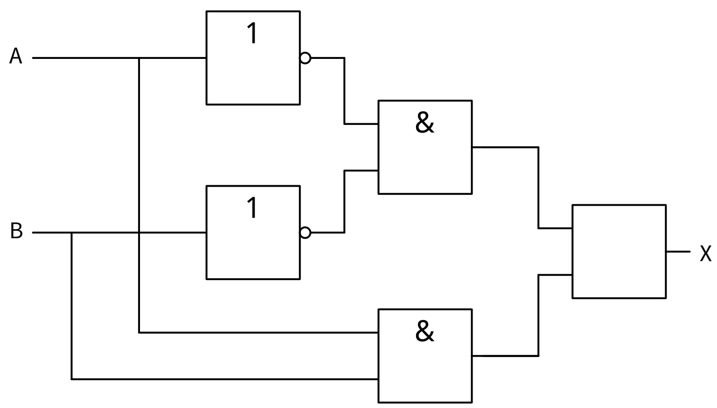
17. What logic gate does the following IEC symbol represent?



AND gate **(1)**

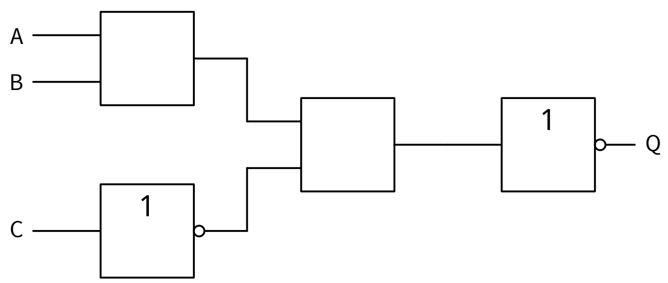
18. Write down the output expression for each of the following gate combinations:

18.1



$\overline{X} = \overline{A}.B + A.B$

18.2

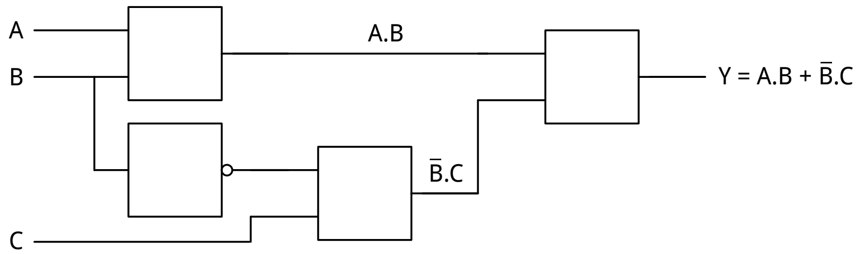


$\overline{(A + B + \overline{C})} = Q$

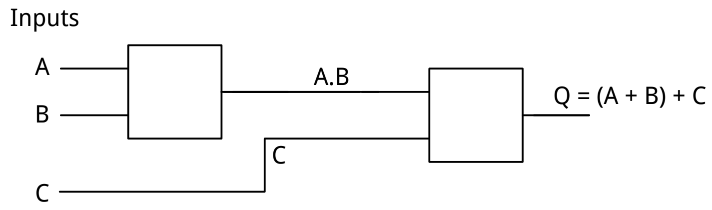
(2 × 2) (4)

19. Draw the logic diagram for the following Boolean expressions:

19.1 Y = A.B + $\overline{\text{B}}$.C **(4)**



19.2 Q = (A + B) + C **(2)**



TOTAL: 59

Module 7

Workshop ethics, safe use of equipment and operational health and safety

After students have completed this module, they should be able to:

- explain the following concepts:
  - occupational health and safety
  - responsibility and rights in relation to a workshop;
- explain various concepts regarding the importance of a safety-first approach in the workshop;
- adhere to safety procedures when soldering and de-soldering on a PC board and Veroboard;
- demonstrate the manual dexterity needed to remove and replace a variety of components on a PC board;
- explain the dangers of electrostatic charges; and
- adhere to safety precautions when handling electrostatic-sensitive devices.

Introduction

Safety is the most important consideration in a workshop and in industry. If the workplace is unsafe, the consequences can be serious, even deadly. The Occupational Health and Safety Act 85 of 1993 (generally referred to as the OHS Act) is the law that aims to protect the well-being of workers. It applies to all organisations, from a normal office environment to the workshop and more hazardous workplaces, such as industrial plants and construction sites.

In this module, we will focus on a safety-first approach in the workshop. Various aspects associated with safety will be covered, including good housekeeping, unsafe conditions, safety signage and the precautions that should be taken when handling soldering equipment, electrical components and charges or electrostatic-sensitive devices.

Activity 7.1

SB page 251

Below is a selection of safety signs. Working in groups, identify the different categories (prohibition/danger, mandatory, warning/caution, emergency/safety and/or fire safety) and determine the meaning of each sign.

1.


No vehicles


No open flames


No smoking

Prohibition/Danger signs

2.

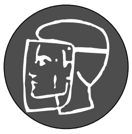

Wear safety glasses


Wear hard hat


Wear ear protection


Wear safety boots


Wear gloves


Wear eye protection/ shield

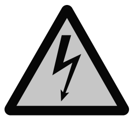
Mandatory signs

3.


General warning

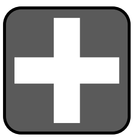

Fire hazard


Hazardous products


High voltage

Warning signs

4.


First-aid kit


Escape route

Emergency/Safety/First-aid sign

Activity 7.2

SB page 251

1. **What is the aim of the Occupational Health and Safety Act?**

   - Protect workers from injuries and illness
   - Protect visitors to the workplace from hazards arising from the activities of workers
   - Prevent accidents by ensuring that people apply general rules regarding health and safety

2. **Name THREE responsibilities of the employer in the workplace.**

   Any THREE of the following:
   - To provide and maintain plant and machinery that are safe and without risks to health
   - To take steps to eliminate or reduce potential hazards to the safety or health of employees at work
   - To provide training necessary to ensure the health and safety of employees at work
   - To ensure that employees understand the hazards associated with the work to be done

3. **What should a worker do the moment he/she becomes aware of any unsafe or unhealthy situation in the workplace?**

   Report the situation to anyone in authority, such as the foreman, shift manager, safety officer, employer.

4. **What is the purpose of human rights in the workplace?**

   Human rights are about ensuring that your human dignity is not infringed upon and that you, as the worker, are treated with dignity and respect and are not exploited.

5. **Name FIVE basic human rights that apply to every South African citizen.**

   Any FIVE of the following:
   - Not to be discriminated against because of your race, sex, religion, language, disability, etc.
   - Earning a living wage
   - Working reasonable hours
   - Belonging to a trade union
   - Not being subjected to slavery or forced labour
   - Having the right to fair labour practices

6. **List THREE advantages of good housekeeping.**

   Any THREE of the following:
   - No time is wasted looking for tools, material and equipment.
   - Space is saved because everything is neatly stacked or stored.
   - The risk of accidents/injuries are reduced.
   - Fire hazards are reduced.
   - Health hazards are reduced when harmful chemicals are stored in a safe designated place.

7. **Define the term *accident*.**

   An accident is an unplanned and uncontrolled event caused by unsafe acts and unsafe conditions.

8. **Explain the difference between an *unsafe act* and an *unsafe condition*.**

   An unsafe act is something that the individual does. Unsafe conditions are the working environment the worker is expected to work in that is not safe.

9. **State whether the following examples are *unsafe acts* or *unsafe conditions*:**

   9.1 **Not leaving a soldering iron in the stand provided when soldering PCBs**

   Act

   9.2 **No apron is provided for the developing of PCBs in an acid bath**

   Condition

   9.3 **Not wearing the safety glasses provided when grinding material**

   Act

   9.4 **Not switching on the extraction fans when workers are handling hazardous materials**

   Act

   9.5 **No isolator switch is provided for the worker who is working on a circuit**

   Condition

10. **Why is it important to work in a well-ventilated workshop?**

    Workshops that are not ventilated well may cause drowsiness, leading to an accident.

11. **Give THREE guidelines for walkways in a workshop.**

    Walkways should be marked clearly, show up under all light conditions and be smooth.

12. **What is meant by *hazardous substances*?**

    According to the Occupational Health and Safety Act, 1993, hazardous substances are defined as "substances that are toxic, corrosive, irritant, strongly sensitising, flammable and pressure generating under certain circumstances".

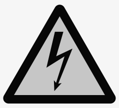
13. **List the purposes of safety signs.**

    - Communicate important instructions quickly and effectively
    - Serve as warning
    - Reinforce safety messages
    - Provide instructions for emergency situations

14. **Why should safety signs be placed between 2 m and 2,5 m above the ground?**

    That is high enough to be above people's heads, but not too high so the sign will not be visible.

15. Complete the table below by filling in the category into which the given safety sign falls and state what it means.

SAFETY SIGN	CATEGORY	MEANING
	Warning/Caution	Flammable material
	Prohibition	No smoking
	Mandatory	Wear safety glasses
	Fire safety	Position of fire hose
	Information	Position of first-aid kit
	Warning/Caution	High voltage, possibility of shock
	Mandatory	Wear gloves

16. Why must we never use a water fire extinguisher on an electrical fire? Give TWO reasons.

It may cause more short circuits and spread the fire and you could be electrocuted.

17. Study the illustration below and make a list of any:

17.1 Unsafe acts

- Standing on forklift to reach higher
- Stacking a ladder on pallet to reach higher
- Standing on pallets to stack boxes higher
- Jumping over safety railing
- Climbing shelve without using a ladder
- Driving forklift over electric cord
- Forklift driver not looking where they are going
- Some people not wearing hardhat
- Person carrying pile of boxes and cannot see where they are going

17.2 Examples of poor housekeeping in the scene

- Exit door blocked
- Tools lying on the floor
- Oils leaking onto floor
- Rubbish bins overfull
- Pallets stacked on the forklift road
- Boxes left on the workshop floor

Summative assessment

SB page 260

1. **Define *soldering*.**

   Soldering can be defined as a low-temperature joining method in which the solder, which is the joining material, has a much lower melting point than the surfaces to be joined. **(3)**

2. **Why should lead-free solder be used for soldering components onto PCBs?**

   Lead-free solder is less toxic and more environmentally friendly. **(2)**

3. **What tool would you use to remove solder from a solder joint?**

   Solder sucker or de-soldering gun **(1)**

4. **Name FIVE safety precautions that should be taken when soldering.**

   Any FIVE of the following:
   - The soldering iron gets very hot (±400 °C). It must be handled with care.
   - Never leave a soldering iron lying on the workbench. Always put it back into its stand when it is not in use to prevent it from causing fires.
   - Lots of harmful fumes are generated during the soldering process, so work in a well-ventilated room
   - Hold wires/components to be soldered with tweezers or clamps to prevent burns.
   - Turn the soldering iron off or unplug it when it is not in use.
   - Always use lead-free solder.
   - When you are soldering, bits of material may fall. Never try to catch hot material with your bare hands.
   - Always wear safety glasses when you solder.
   - Take care not to let the nozzle of the solder sucker touch the hot tip of the soldering iron, as this will melt the plastic nozzle.

- When de-soldering, take care not to apply too much heat to the joint, as this may damage the sometimes-thin copper tracks.
- After handling solder, make sure you wash your hands thoroughly. **(5)**

5. **Why is manual dexterity required when soldering?**

Soldering requires fine motor skills using hand-eye coordination. You must be able to solder and de-solder in a small area using very small components. **(3)**

6. 6.1 **Define** ***static electricity*****.**

Static electricity is the build-up of electrical charges on the surface of some object or material. **(2)**

6.2 **Give TWO examples of where you are likely to encounter static electricity.**

When you comb your hair or touch a metal object, such as a doorknob, after walking across a carpet (Any acceptable example) **(2)**

7. **Why is it dangerous to touch something with a very high static charge?**

The charge will flow through your body, causing an electric shock. This could cause burns or even stop your heart. **(3)**

8. **Name THREE precautions that should be taken to make a work area static-free.**

Any THREE of the following:

- Wearing anti-static wrist straps will provide a high-resistance path for the static charge in the body to ground
- Ensuring that all conductive and metal parts of the work area are bonded and earthed, allowing the discharge of electrostatic electricity to travel to the ground
- Replacing all tools with anti-static tools
- Using anti-static mats on floors and work surfaces
- Wearing anti-static clothing
- Removing clutter, e.g. plastic, vinyl and foam from static-protected workstations
- Keeping the work area relatively dry and free from humidity
- Posting signs and labels to remind staff and visitors to remain static-free **(3)**

9. **How does a wrist band help with static charges?**

Wearing anti-static wrist straps will provide a low-resistance path for the static charge in the body to ground. **(2)**

10. **Name TWO common components prone to be damaged by static charge.**

Any TWO of the following:

- Metal-oxide semiconductor field-effect transistors (MOSFETs) used to build ICs
- Complementary metal-oxide semiconductors used to build ICs (i.e. ICs built with MOSFETs), e.g. computer CPUs, graphics ICs, etc.
- Computer cards
- Transistor-transistor logic ICs
- Laser diodes
- Blue LEDs
- High-precision resistors **(2)**

11. Name THREE precautions that should be taken when you assemble a PCB.

Any THREE of the following:

- Keep the device/component in a static-safe container or bag until it arrives at the static- protected workstation and is ready to be installed.
- Limit your movement on the assembly and testing lines. Movement can cause static electricity to build up around you.
- Handle the device/component carefully, holding it by its edges or frame.
- Avoid touching pins, leads or circuitry.
- Do not touch solder joints, pins or exposed printed circuitry
- Ensure you wear anti-static clothing and foot gear.
- Always wear your anti-static wrist band.
- Use special anti-static tools.
- Always be properly grounded when touching static-sensitive components or devices. **(3)**

TOTAL: 31

Glossary

A

Acoustic – relating to sound or sense of hearing

Ammeter – instrument for measuring electric current in amperes

Amplification – increasing the amplitude (voltage/current) of a time-varying signal by a given factor

Amplifier – generic term used to describe a circuit that produces an increased version of its input signal

Analogue – relating to or using signals or information represented by a continuously variable physical quantity such as voltage or spatial position

Anion – negatively charged ion, i.e. one that would be attracted to the anode in electrolysis

Annealed – heated and allowed to cool slowly

Arc (of circle) – part or segment of the circumference of a circle

Arcing – bright electrical discharge between two points

Atom – smallest part of a chemical element that can exist

Auto-polarity – automatic interchanging of connections to a digital meter when polarity is wrong; a minus sign appears ahead of the value on the digital display if the reading is negative

Avalanche effect – sudden increase in the flow of an electrical current through a non-conducting or semiconducting solid when a sufficiently strong electrical force is applied

B

Base unit (in international SI measurement) – fundamental unit that is defined arbitrarily and not by combinations of other units

Biasing – arrangement made in a diode or other electrical device to allow a larger flow of current in a certain direction

Binary – relating to a numbering system that has only two possible values for each digit, namely 0 or 1

Bipolar transistor – type of transistor that uses both electrons and electron holes as charge carriers

Bond – link or force between neighbouring atoms in a molecule or compound

Boolean expression – logical statement that is either true or false

Boolean logic – system of algebraic notation used to represent logical propositions by means of the binary digits 0 (false) and 1 (true)

Breadboard – thin, plastic board with tiny holes for building an experimental model of an electric circuit

C

Capacitance – ratio of the amount of electric charge stored on a conductor to a difference in electric potential

Cation – positively charged ion, i.e. one that would be attracted to the cathode in electrolysis

Cell – single unit of a battery that generates a DC voltage by converting chemical energy into electrical energy

Circuit – complete and closed path around which a circulating electric current can flow

Clock pulse – continuous train of even, square wave pulses

Cone – 3D shape in geometry that narrows smoothly from a flat circular base to a point

Constantan – copper-nickel alloy used in electrical work for its high resistance

Continuity – presence of a complete path for current flow

Convert – to change a value or expression from one form to another

Corrosive – materials that contain acid, chloride or other harmful substances that can burn or damage the skin

Covalent bonding – chemical bonding in which two atoms share some of their valence electrons, thereby creating a force that holds the atoms together

Current – number of electrons flowing through an electric circuit; standard unit of measurement is ampere (A)

D

Decimal notation – representation of a fraction or other real number using the base 10 and consisting of any of the digits 0 to 9 and a decimal point

Depletion region – region between an N-type and P-type materials where there is neither an excess of electrons nor of holes

Digital – signals/data expressed as a series of the digits 0 to 1, typically represented by values of a physical quantity such as voltage

Digital timing diagram – representation of a set of signals in the time domain

Diode – electrical component that allows the flow of current in only one direction

Discrete circuit – electronic circuit constructed of components that are manufactured separately

Dissipate – cause energy to be lost through its conversion to heat

Doping – process of adding certain chemical elements to a semiconductor to change its electrical conductivity

E

Earth – wire that provides an electrical connection to the ground to protect against electric shock

Echolocation – physiological process for locating distant or invisible objects by means of sound waves reflected to the emitter (such as a bat) by the objects

Electric current – movement of positive or negative electric particles (such as electrons) accompanied by observable effects such as the production of heat, a magnetic field or chemical transformations

Electrolytic capacitor – capacitor that uses an electrolyte to produce a larger capacitance than other capacitors

Electron – stable subatomic particle with a charge of negative electricity, found in all atoms and acting as the primary carrier of electricity

Electrostatic charge – charge generated by friction between two surfaces

Element – substance that contains only one kind of atom; cannot be chemically broken down into simpler substances and is the primary constituent of matter

Energy levels – fixed distances from the nucleus of an atom where electrons can be located

Ergonomic(s) – science concerned with designing and arranging the working environment to the benefit of workers

Extrinsic semiconductor – semiconductor to which a trace element or chemical is added during manufacturing

F

Farad – SI unit of electrical capacitance

Fine motor skills – coordination of small muscles in movement with the eyes, hands and fingers

Fire extinguisher – portable device that discharges a jet of water, foam, gas or other material to extinguish a fire

First aid – help given to sick or injured person until full medical treatment is available

G

Gain – ratio of the output signal compared to the input signal of an amplifier

H

Hazard – any source of potential damage, harm or adverse health effects

Hysteresis – phenomenon in which the value of a physical property lags behind changes in the effect causing it, e.g. when magnetic induction lags behind the magnetising force

I

Infinity – unlimited extent of time, space or quantity

Insulation – non-conductive material used to cover electrical wiring

Insulator – substance that does not allow the flow of electric current

Integrated circuit – assembly of electronic components, manufactured as a single unit, in which minute devices (transistors, diodes, capacitors and resistors) and their interconnections are built up on a thin piece of silicon or germanium

Intrinsic semiconductor – chemically pure semiconductor, i.e. free from impurities

Ionic bonding – attraction between two atoms, involving the sharing of one or more electrons; typically formed between two nonmetals

Ionised – the atom/molecule is converted into an ion or ions, typically by removing one or more electrons

L

LCD (liquid-crystal display) – flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid

LDR – component that has a variable resistance that changes with the light intensity to which it is exposed

Lead – metal connection placed on a component to enable the connection of the component to an electric circuit

Loading effect – extent to which an instrument affects electrical properties such as voltage, current and resistance of the circuit being tested

Luminous intensity – quantity of visible light that is emitted in unit time per unit solid angle (*sterdian*)

M

Magnetic field – region around a moving electric charge within which the force of magnetism acts

Manual dexterity – ability to use one's hands to perform a difficult task skilfully and quickly

Mass produced – standardised article produced in large quantities by an automated mechanical process in a factory

Matter – physical substance made up of molecules and which occupies space and has mass

Microchip – tiny wafer of semiconducting material used to make an integrated circuit

Molecule – group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction

Moving-coil meter – measuring instrument in which current or voltage is determined by the force on a small coil pivoted between the poles of a magnet with curved poles, creating a radial magnetic field

Moving-iron meter – measuring instrument in which a vane or disc of soft iron is moved by the magnetic field set up by a coil carrying the current to be measured

Multimeter – instrument used to measure the properties of an electric circuit, such as resistance, voltage and current

Multiplier – series resistor that multiplies the working range of a voltmeter as the resistor proportionately divides the voltage across it

N

N-type – extrinsic semiconductor that has been doped with electron donor atoms; the majority of charge carriers are negative electrons

Neutron – subatomic particle of about the same mass as a proton, but without an electric charge, present in all atomic nuclei (except those of ordinary hydrogen)

Nucleus – positively charged central core of an atom

O

Ohmmeter – instrument for measuring electrical resistance in ohms

Orbit – regular, repeating path of an electron round an atomic nucleus

Orbital – location and wave-like behaviour of an electron in an atom

P

P-type – extrinsic semiconductor that has been doped with trivalent impurity so that it has an excess of electron holes

Parallax error – perceived shift in an object's position as it is viewed from different angles

PCB (printed circuit board) – electronic circuit used in devices to provide mechanical support and a pathway to its electronic components

Pentavalent impurity – elements that have five valence electrons in the outermost orbit of the atom

Phase separation – separation of fluid phases that contain different concentrations of common components

Photolithography – standard method of PCB and microprocessor manufacturing; process uses light to make the conductive paths of a PCB layer and the paths and electronic components in the silicon wafer of microprocessors

Passive infrared (PIR) – device used to detect motion by receiving infrared radiation

PIV (peak inverse voltage) – voltage at which a diode can start conducting when it is reverse biased

Polarised – can only be connected in a circuit in one direction

Polarised capacitor – capacitor that has specific positive and negative polarity that must be connected correctly in circuits

Polarity – directional flow of electrons from one pole to the other

Pole – number of circuits controlled by a switch, e.g. single-pole switches control only one electric circuit, while double-pole switches control two independent circuits

Power factor – ratio between active power and apparent power

Prefixes – unit abbreviations that precede basic units of measurement to indicate a multiple or submultiple of the units

Proton – stable subatomic particle found in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron

Prototyping – building a circuit based on a given design to see if it works; if it does not work properly, the circuit can be adjusted

Pyroelectric – having the property of becoming electrically charged when heated

R

Radius (of circle) – straight line from the centre of a circle to the circumference

Range – upper and lower limits an instrument can measure a value or signal such as amperes, volts and ohms

Rating – indicates the voltage at which a component is designed to work and current consumption at that voltage

Rectification – conversion of AC to DC

Repulsion – force that causes bodies or particles to repel (push away) one another

Resistance – amount of resistance the circuit offers to the current flowing through it; standard unit of measurement is ohm (Ω)

Resistivity – property of a material that indicates how much it resists the flow of electric current

Rheostat – electrical component used to control a current by varying the resistance

Right – moral or legal entitlement (claim) to have or do something

S

Scientific notation – method of expressing a given quantity as a number having significant digits necessary for a specified degree of accuracy

Semiconductor – material that has conductivity between a good conductor (generally metals) and a good insulator but that can conduct electricity under certain conditions

Sensitising – causing a harmful reaction

Sensor – device that detects a physical parameter of interest (e.g. heat, light, sound)

Shell – pathway or set of orbitals around the nucleus of an atom, occupied or able to be occupied by electrons of similar energies

Shunt – parallel resistor that extends the working range of an ammeter, as the resistor proportionately divides the current between two branches

Signal generator – electronic devices that generates electronic signals with set properties of amplitude, frequency and wave shape

Socket – plug-in point for receiving the lead of the meter

Solder – alloy (usually with a lead, brass, tin or silver base) with a low melting point; used for joining metals

Spindle – rod or pin serving as an axis that revolves or on which something revolves

Stability – ensuring the amplifier has a constant gain over a large range of input signals

T

Thermistor – electrical resistor whose resistance is greatly increased or reduced by heating; used for measurement and control

Throw – extreme position of the actuator; single-throw switches close a circuit at only one position, while double-throw switches close a circuit in the up as well as in the down position (on-on)

Tolerance – deviation from the nominal value expressed as an approximate percentage, measured at 25 °C with no load applied

Toroidal sensor – conductive sensor made of two metal toroids (coils of insulated or enamelled wire wound on a doughnut-shaped form made of powdered iron)

Torque – measure of the force that can cause an object to rotate about an axis

Toxic – poisonous; extremely harmful; can even be deadly

Transducer – electronic device that converts energy from one form to another

Trivalent impurity – doping materials that have three electrons in the outermost shell of the atom

Truth table – mathematical table that shows all the possible outcomes from all the scenarios considered at the input

U

Ultrasonic – any device that uses sound waves with a frequency above the upper limit of human hearing

V

Valence electron – single electron or one of two or more electrons in the outer shell of an atom; responsible for the chemical properties of the atom

Vane – thin, flat or curved object that is rotated about an axis by magnetic fields

Vertex – point where two or more line segments meet

Voltage – electric 'pressure' in an electric circuit; standard unit of measurement is volt (V)

Voltmeter – instrument for measuring electric potential in volts

Z

Zener diode – special type of diode designed to allow current to flow in reverse bias when a certain reverse voltage, known as Zener voltage, is applied

References

Abelson, H., Sussman, G.J. (1996). *Structure and Interpretation of Computer Programs*, 2nd edition. Series MIT Electrical Engineering and Computer Science.

Bell, T., Witten, I.H., Fellows, M. (1998). *Computer Science Unplugged*. Off-line activities and games for all ages.
http://unplugged.canterbury.ac.nz

Bloem, J. et al., 2014. *The fourth industrial revolution – Things tighten*.
Available at: https://www.sogeti.com/globalassets/global/special/sogeti-things3en.pdf.

Anon, *C++ Glossary – Step by Step Programming*.
Available at: https://sites.google.com/site/simplestjava/c-glossary
[Accessed August 14, 2019].

Anon, *gdbgui*.
Available at: https://www.gdbgui.com/[Accessed August 14, 2019].

Asgedom, N., 2021. *Robotic and block-based programming with Text Interpreter for motivating novice programmers*. Master's thesis, Itä-Suomen yliopisto, 2021.

Candido, R. (2019). *Arduino With Python: How to Get Started*.
Available at: https://realpython.com/arduino-python/

Corke, P., Haviland, J. (2021). *Not your grandmother's toolbox – the Robotics Toolbox reinvented for Python*. In IEEE International Conference on Robotics and Automation.

Ellen Frederick, D. (2016). *Libraries, data and the fourth industrial revolution (Data Deluge Column)*. Library Hi Tech News, 33(5), pp.9–12.

Fernandez, et al. 2015

Futurelearn.com (2021). *Programming skills for robotics*. Available at: https://www.futurelearn.com/info/courses/robotic-future/0/steps/29368

Ginat, D. (2006). *On novices' local views of algorithmic characteristics*.
In: Mittermeir, R.T. (Ed.): ISSEP 2006, LNCS, 4226, 127–137.

Govender, I. (2006). *Learning to Program, Learning to Teach Programming: Pre- and In-service Teachers' Experiences of an Object-oriented Language*. University of South Africa.

Hromkovič, J. (2006). *Contributing to general education by teaching informatics*.
In: Mittermeir, R.T. (Ed.), ISSEP 2006, LNCS, 4226, 25–37.

Hymel, S. (2021). *Python Programming Tutorial: Getting Started with the Raspberry Pi*.
Available at: https://learn.sparkfun.com/tutorials/python-programming-tutorial-getting-started-with-the-raspberry-pi/programming-in-python

Joseph L. (2018). *Fundamentals of C++ for Robotics Programming*.
In: Robot Operating System (ROS) for Absolute Beginners. Apress, Berkeley, CA

King, P (n.d.). *Simple electronics with GPIOZero*, The Magpi magazine.
Online available at: https://www.mclibre.org/descargar/docs/revistas/magpi-books/the-magpi-essentials-gpiozero-01-en-201608.pdf

Kong, S.C. & Wang, Y.Q. (2021). *The influence of parental support and perceived usefulness on students' learning motivation and flow experience in visual programming: Investigation from a parent perspective*. British Journal of Educational Technology

Mannila, L. (2007). *Novices' progress in introductory programming courses*.
Informatics in Education, 6, 139– 152.

Anon, MinGW. *Minimalist GNU for Windows*.
Available at: http://www.mingw.org/[Accessed August 14, 2019].

Meerbaum-Salant, O., Armoni, M. & Ben-Ari, M. (moti), 2013. *Learning computer science concepts with Scratch*. Computer Science Education, 23(3), pp.239–264.

Mehla, A. (2021). *Python Language advantages and applications* – GeeksforGeeks Available at: https://www.geeksforgeeks.org/python-language-advantages-applications/

Mulder, F. (2002). *van BÈTA – na DELTA-discipline*
(in English: *Computer Science: from a BÈTA to a DELTA subject*).
Informatica, Tinfon, 11, 48.

Owen-Hill, A. (2018). *Python vs C++ vs C# vs MATLAB: Which Robot Language is Best?*.
Available at: https://robodk.com/blog/robot-programming-language/

O'Hanlon, M. (2019). *Scratch 3 Desktop for Raspbian on Raspberry Pi?*
Available at: https://www.raspberrypi.org/blog/scratch-3-desktop-for-raspbian-on-raspberry-pi/

Papert, S. (1980). *Mindstorms – Children, Computers and Powerful Ideas*.
Basic Books, Inc. Publishers, New York.

Practpoint, 2019. File:PHP – Learn php programming online programming practice.jpg.
Available at: https://commons.wikimedia.org/wiki/File:PHP_-_learn_php_programming_online_programming_practice.jpg [Accessed July 4, 2019].

RoboticsBackend.com (2021). *When To Use Python vs C++ in Robotics?*
Available at: https://roboticsbackend.com/when-to-use-python-vs-c-in-robotics/

Resnick, M.; Maloney, J.; Monroy-Hernández, A.; Rusk, N.; Eastmond, E.; Brennan, K.; Millner, A.; Rosenbaum, E.; Silver, J.; Silverman, B.; Kafai, Y. (2009).
Scratch: Programming for all. Communications of the ACM, November 2009.

Saeli, M. et al., 2011. *Teaching Programming in Secondary School: A Pedagogical Content Knowledge Perspective*. Informatics in Education, 10(1), pp.73–88.

Syslo, M.M. Kwiatkowska, A.B. (2006). *Contribution of informatics education to mathematics education in schools*.
In: Mittermeir, R.T. (Ed.), ISSEP 2006, LNCS, 4226, 209–219.

Shulman, L.S. (1986). *Those who understand: knowledge growth in teaching*.
Educational Researcher, 15, 4–14.

udacity.com (2021). *Should I Learn C or C++?*
Available at: https://www.udacity.com/blog/2021/05/should-i-learn-c-or-cpp.html

Vaish, D. (2018). *Python Robotics Projects: Build smart and collaborative robots using Python*.
Packt Publishing Ltd

Van Schooneveld, J. (2020). *Build Physical Projects With Python on the Raspberry Pi*. Available at: https://realpython.com/python-raspberry-pi/