MINISTRY OF EDUCATION

Engineering

TEACHER MANUAL

YEAR 1 - BOOK 1

NaCCA
NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Engineering

Teacher Manual

Year One - Book One

NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION

ENGINEERING TEACHERS MANUAL

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CONTENTS

INTRODUCTION

The National Council for Curriculum and Assessment (NaCCA) has developed a new Senior High School (SHS), Senior High Technical School (SHTS) and Science, Technology, Engineering and Mathematics (STEM) Curriculum. It aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, competencies, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, further their education and enter the world of work.

This is the first time that Ghana has developed an SHS Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

This Teacher Manual for Engineering covers all aspects of the content, pedagogy, teaching and learning resources and assessment required to effectively teach Year One of the new curriculum. It contains this information for the first 13 weeks of Year One, with the remaining 11 weeks contained within Book Two. Teachers are therefore to use this Teacher Manual to develop their weekly Learning Plans as required by Ghana Education Service.

Some of the key features of the new curriculum are set out below.

Learner-Centred Curriculum

The SHS, SHTS, and STEM curriculum places the learner at the center of teaching and learning by building on their existing life experiences, knowledge and understanding. Learners are actively involved in the knowledge-creation process, with the teacher acting as a facilitator. This involves using interactive and practical teaching and learning methods, as well as the learner's environment to make learning exciting and relatable. As an example, the new curriculum focuses on Ghanaian culture, Ghanaian history, and Ghanaian geography so that learners first understand their home and surroundings before extending their knowledge globally.

Promoting Ghanaian Values

Shared Ghanaian values have been integrated into the curriculum to ensure that all young people understand what it means to be a responsible Ghanaian citizen. These values include truth, integrity, diversity, equity, self-directed learning, self-confidence, adaptability and resourcefulness, leadership and responsible citizenship.

Integrating 21st Century Skills and Competencies

The SHS, SHTS, and STEM curriculum integrates 21st Century skills and competencies. These are:

- **Foundational Knowledge:** Literacy, Numeracy, Scientific Literacy, Information Communication and Digital Literacy, Financial Literacy and Entrepreneurship, Cultural Identity, Civic Literacy and Global Citizenship
- **Competencies:** Critical Thinking and Problem Solving, Innovation and Creativity, Collaboration and Communication
- **Character Qualities:** Discipline and Integrity, Self-Directed Learning, Self-Confidence, Adaptability and Resourcefulness, Leadership and Responsible Citizenship

Balanced Approach to Assessment - not just Final External Examinations

The SHS, SHTS, and STEM curriculum promotes a balanced approach to assessment. It encourages varied and differentiated assessments such as project work, practical demonstration, performance assessment, skills-based assessment, class exercises, portfolios as well as end-of-term examinations and final external assessment examinations. Two levels of assessment are used. These are:

- o Internal Assessment (30%) – Comprises formative (portfolios, performance and project work) and summative (end-of-term examinations) which will be recorded in a school-based transcript.
- o External Assessment (70%) – Comprehensive summative assessment will be conducted by the West African Examinations Council (WAEC) through the WASSCE. The questions posed by WAEC will test critical thinking, communication and problem solving as well as knowledge, understanding and factual recall.

The split of external and internal assessment will remain at 70/30 as is currently the case. However, there will be far greater transparency and quality assurance of the 30% of marks which are school-based. This will be achieved through the introduction of a school-based transcript, setting out all marks which learners achieve from SHS 1 to SHS 3. This transcript will be presented to universities alongside the WASSCE certificate for tertiary admissions.

An Inclusive and Responsive Curriculum

The SHS, SHTS, and STEM curriculum ensures no learner is left behind, and this is achieved through the following:

- Addressing the needs of all learners, including those requiring additional support or with special needs. The SHS, SHTS, and STEM curriculum includes learners with disabilities by adapting teaching and learning materials into accessible formats through technology and other measures to meet the needs of learners with disabilities.
- Incorporating strategies and measures, such as differentiation and adaptative pedagogies ensuring equitable access to resources and opportunities for all learners.
- Challenging traditional gender, cultural, or social stereotypes and encouraging all learners to achieve their true potential.
- Making provision for the needs of gifted and talented learners in schools.

Social and Emotional Learning

Social and emotional learning skills have also been integrated into the curriculum to help learners to develop and acquire skills, attitudes, and knowledge essential for understanding and managing their emotions, building healthy relationships and making responsible decisions.

Philosophy and vision for each subject

Each subject now has its own philosophy and vision, which sets out why the subject is being taught and how it will contribute to national development. The Philosophy and Vision for Engineering is:

Philosophy: The next generation of creators and technology developers can be empowered through observation, curiosity, exposure to related engineering concepts and opportunities that leverage practical activities in a learner-centred environment, leading to global and local ("glocal") relevance.

Vision: A skilled learner armed with 21st-century skills and competencies in critical thinking, designing, and development of engineering-based solutions for increasingly complex societal problems

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SCOPE AND SEQUENCE

Engineering Summary

S/N	STRAND	SUB-STRAND	YEAR 1			YEAR 2			YEAR 3		
			CS	LO	LI	CS	LO	LI	CS	LO	LI
1	Engineering Practice	Engineering In Society	1	2	5	1	1	2	1	2	4
		Health And Safety In Engineering Practice	1	2	4	1	2	6	1	2	4
		Ethics And Professional Practice	1	2	4	1	2	6	1	1	3
2	Energy System	Circuit And Machines	1	2	7	1	2	5	1	2	4
		Renewable Energy System	1	2	4	1	2	4	1	2	4
		Energy Efficiency And Conservation	1	2	4	1	2	4	1	2	4
3	Systems Design And Prototyping	Engineering Design	1	2	4	2	2	2	2	2	2
		Rapid Prototyping	1	1	1	2	2	2	2	2	2
4	Automation And Embedded System	Automation Technologies	1	2	2	1	1	1	1	2	2
		Embedded System	2	4	6	2	2	2	1	1	1
Total			**11**	**21**	**41**	**13**	**18**	**34**	**12**	**18**	**30**

Overall Totals (SHS 1 – 3)

Content Standards	**36**
Learning Outcomes	**57**
Learning Indicators	**105**

SECTION 1: ENGINEERING PRACTICE IN SOCIETY

Strand: **Engineering Practice**

Sub-Strand: Engineering in Society

Learning Outcome: *Identify engineering footprints in learners' communities*

Content Standard: Demonstrate an understanding of the place of Engineering in societal development.

INTRODUCTION AND SECTION SUMMARY

In this section, learners will be introduced to the role and responsibilities of engineers in society through the observation of engineering works in their community. They will understand the role of the various engineering disciplines in accomplishing a given engineering project. Emphasis is put on the fact that real world problems cannot be solved using expertise of only one knowledge domain. Problems of the society are almost always solved by professionals from different engineering domains working together, thus necessitating the acquisition of collaborative and problem-solving skills. In addition, learners will be able to describe the role of various engineers as well as the contributions of various engineering occupations in solving a societal problem. Furthermore, learners will begin to identify with various engineering professions based on their individual interests and needs; and begin to assess their career choices in the field of Engineering. Engineering skills are highly transferable across different disciplines. The core principles of problem-solving, critical thinking, communication, collaboration, and innovation is applicable in various engineering domains. An engineer who excels in one area can adapt their skills to address challenges in other fields, fostering interdisciplinary collaboration and accelerating innovation.

The weeks covered by the section are:

Week 1: Engineering in Society

Week 2: The Interdisciplinarity of Engineering Disciplines for Problem-solving

SUMMARY OF PEDAGOGICAL EXEMPLARS

Recognising that, learners have different backgrounds, different learning abilities and different ways of learning, it is important to select from a wide variety of teaching methods suitable for the different categories of learners in the class. Think-pair-share, field trip to the communities, pyramid discussion, mixed ability grouping, etc are some pedagogical options to consider. Consider giving learners an opportunity to watch a video on a major engineering project or go on a field trip to some engineering project sites in the community. Let learners share their experiences through pyramid discussion to come out with various engineering occupational disciplines. In mixed ability grouping, learners outline the contributions of each engineering discipline in solving societal problems. A case study of a problem within the school community can also be considered so that learners working in groups have opportunity to discuss what skills and competencies of the various engineering disciplines are required to solve the problem. Finally, a research project can be considered so that learners can dive deeper into the contribution of Engineering to solving societal problems.

ASSESSMENT SUMMARY

Various categories of assessment modes should be considered to afford all categories of learners the opportunity to express their understanding of the major themes in the section. Oral responses can be elicited in class discussions following a visit to an engineering project site; written responses, of various level of difficulties appropriate for the class can also be requested from learners, relative to the major concepts in this section. Learners can also be engaged in a project, where they visit their respective communities during the vacation, observe and or conduct survey in the community to determine the most pertinent problems in their communities and outline the various engineering skills and competencies required to solve such a problem. These should contribute to learners' formative assessment.

Learners can also be encouraged to outline their own solutions to the identified problems and present a written, oral or power point presentation in class; which can contribute to learners' summative assessment.

Week 1

Learning Indicator(s):

1: *Classify the various engineering occupational disciplines*
2: *Outline the contributions of each engineering discipline in solving societal problems*

Theme or Focal Area 1:

Engineering is a broad discipline and profession that involves the application of scientific, mathematical, and practical knowledge to design, create, improve, and maintain systems, structures, machines, devices, processes, and materials. The major Engineering disciplines are Civil engineering, Mechanical engineering, Electrical engineering, Chemical engineering, Aerospace engineering, and Computer science and Engineering, Biomedical engineering, Environmental engineering.

1. **Civil Engineering:** Civil engineering deals with the design, construction, and maintenance of infrastructure and facilities essential for modern society.

Figure 1: A picture of a civil engineer at work.

Source: istockphoto.com, url: https://shorturl.at/opr57, [accessed: 21.03.2024]

2. **Mechanical Engineering**: Mechanical engineering involves the study of mechanical systems and their components to design, analyse, and manufacture devices that move or have moving parts.

Figure 2: A picture of mechanical engineers at work

Source: autoreportafrica.com, url: https://shorturl.at/exJS8, [accessed: 21.03.2024]

3. **Electrical Engineering:** Electrical engineering deals with the study and application of electricity, electronics, and electromagnetism.

Figure 3: A picture of electrical engineers at work

Source: newsghana.com.gh, url: https://shorturl.at/fuvI4, [accessed: 21.03.2024]

4. **Chemical Engineering:** Chemical engineering combines principles of chemistry, physics, and biology to design and optimise processes for converting raw materials into useful products on an industrial scale.

Figure 4: A picture of chemical engineers at work

Source: lens.google.com, url: https://shorturl.at/dKZ39, [accessed: 21.03.2024]

5. **Aerospace Engineering:** Aerospace engineering deals with the design, development, and production of aircraft and spacecraft while Aeronautical engineering is the study of aircraft that operates within the earth's atmosphere.

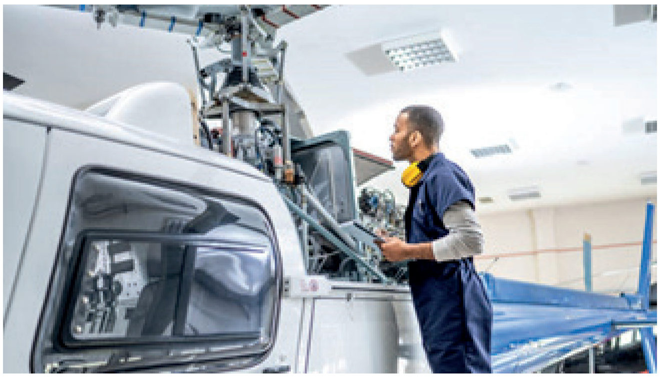

Figure 5: Picture of an aerospace engineer at work

Source: istockphoto.com, https://shorturl.at/duxMR, [accessed: 21.03.2024]

6. **Computer Science and Engineering:** Computer science and engineering involve the study of computer systems, software development, and computational technologies.

Figure 6: A picture of a computer engineer at work

Source: lens.google.com, url: https://shorturl.at/DJKNS, [accessed: 21.03.2024]

7. **Biomedical Engineering:** Biomedical engineering applies engineering principles to solve challenges in the field of medicine and healthcare.

Figure 7: A picture of a biomedical engineer at work

Source: lens.google.com, url: https://shorturl.at/pzHN5, [accessed: 21.03.2024]

8. **Environmental Engineering:** Environmental engineering addresses environmental issues and sustainability by designing solutions to protect and improve the natural environment.

Figure 8: A picture of an environmental engineers at work

Source: shutterstock.com, url: https://shorturl.at/vEQRS, [accessed: 21.03.2024]

Learning Task

1. Discuss the major disciplines in Engineering.
2. Support Learners to classify twenty (20) works observable within their communities into Engineering occupations.
3. Discuss the main sub-disciplines within Mechanical engineering, and how they contribute to various industries?
4. Distinguish between seemingly closely related engineering fields discuss the industries in which engineers of those fields play a vital role in.
5. Ask Learners to discuss the key responsibilities of the various engineering fields and also how their work overlap with those of related fields.
6. Discuss the role of biomedical engineers in healthcare, and how they collaborate with medical professionals.
7. Discuss the contributions of each engineering discipline in solving problems identified within the school environment.
8. Discuss emerging engineering disciplines and outline their contributions to solving pertinent and complex societal problems.
9. Visit a nearby engineering project and facilitate Learners interaction with the engineering professionals working on those projects.
10. Watch video documentaries of major accomplishments of various engineering disciplines and have learners discuss their observations.

Theme or Focal Area 2:

The various fields of engineering are instrumental in addressing important societal issues, including but not limited to clean energy, water resource management, infrastructure and transportation development, advancements in healthcare technology, effective disaster management, efficient waste disposal systems, innovations in education technology, and the creation of solutions to enhance accessibility.

The following are some fields of engineering.

1. **Civil Engineering:** Civil engineers design and construct roads, bridges, buildings, water supply systems, and wastewater treatment facilities, improving transportation and urban living conditions; infrastructure development, environmental solutions, disaster resilience.
2. **Mechanical Engineering**: Mechanical engineers contribute to the development of renewable energy technologies, energy-efficient systems, and advancements in power generation and distribution. Mechanical engineers work on designing more energy-efficient machines and systems to reduce energy consumption and greenhouse gas emissions, helping to combat climate change, energy solutions, transportation, manufacturing and robotics
3. **Electrical Engineering:** Electrical engineers work on creating efficient power generation methods and smart grid systems, ensuring reliable and widespread access to electricity, especially in remote areas. They contribute to the development of communication technologies, improving connectivity and facilitating information exchange globally; power generation and distribution, electronics and communication, automation and control.
4. **Chemical Engineering:** Chemical engineers design and implement processes to reduce pollution, manage waste, and develop eco-friendly materials and chemicals. They play a role in developing safe and sustainable food production methods and pharmaceutical manufacturing processes, improving public health; sustainable processes, pharmaceuticals and healthcare, food and beverage industry.
5. **Aerospace Engineering:** Aerospace engineers contribute to exploring outer space, conducting research, and developing technologies that benefit various scientific fields and inspire future generations. They work on designing safer, more efficient aircraft, Unmanned Aerial Vehicles (UAVs, also known as drones) and air traffic management systems, ensuring global connectivity and enhancing air travel safety; aviation and space exploration, defence and security.
6. **Environmental Engineering:** Environmental engineers work on water treatment, distribution, and conservation, addressing water scarcity and improving water quality. They promote environmentally friendly practices in industries and urban planning, striving for a more sustainable and resilient future; water resources management, waste management, renewable energy.
7. **Biomedical Engineering:** Biomedical engineers contribute to designing and developing medical devices, prosthetics, and diagnostic tools, improving healthcare outcomes and enhancing the quality of life for patients. They work on creating assistive technologies and rehabilitation devices to support individuals with disabilities and improve their independence; medical devices and technology, tissue engineering and regenerative medicine, healthcare systems improvement.
8. **Computer Engineering and Software Engineering:** Computer engineers develop and optimise hardware and software solutions, fostering advancements in communication, education, research, and various other sectors. They work on securing digital systems and protecting sensitive information from cyber threats, ensuring data privacy and the safe use of technology; Information Technology, Data Analysis and Artificial Intelligence (AI).

Learning Task

1. Discuss with learners the role of civil engineering in addressing societal challenges related to urbanisation and population growth. Provide examples of infrastructure projects that have positively impacted communities.
2. Discuss the role of other engineering professionals as well as their contribution to the development and implementation of various technologies for societal comfort. How does these engineering disciplines impact the environmental?

3. Engage learners in a brainstorming session on the collaborative approach of engineering professionals in tackling societal problem, such as pollution, sanitation etc. Discuss which engineering disciplines would be involved, and how their expertise complement each other.
4. Have learners working in mixed-ability and mixed-gender groupings to brainstorm and design a comprehensive disaster management plan for a region prone to natural disasters such flooding, earthquake etc. How can civil engineering, environmental engineering, and electrical engineering contribute to this plan to minimise the impact on communities?
5. Visit a nearby engineering project and facilitate learners interaction with the engineering professionals working on those projects to appreciate the roles those engineers play on the project.
6. Watch video documentaries of major accomplishments of various engineering professionals and have learners discuss their observations.
7. Have learners do mini projects and present their work as posters discussion the contributions of engineers to solving societal problems.
8. Invite an Engineering Professional to make a presentation to learners on the contribution of engineering professionals to developing the projects and technologies that benefit society.

Pedagogical Exemplars

Managing talk-for-learning: In a moderated discussion, learners share their thoughts, experiences, and knowledge they have of the various engineering disciplines.

Experiential learning: Invite two (2) engineers to speak about their professional practice, experience, challenges, and opportunities.

Experiential learning: Where possible, lead learners to visit an engineering site to interact with various engineering professionals.

Case Study

A case study of a problem or a project within the school community can be considered. Learners working in groups will have the opportunity to

1. discuss what engineering competencies of the various engineering disciplines are required to solve the problem or complete the project.
2. What other skills and competencies (e.g. collaboration, critical thinking, problem solving and communication) that are required to solve the problem or complete the project.

Enquiry-based learning:

Learners working in groups to conduct research on emerging themes, topics, concepts etc in Engineering, (AI, 6G, Cloud Computing, etc); and present to the class; so, learners can dive deeper into the contribution of engineering professions to solving societal problems.

Project based learning:

Learners can also be asked to find out problems or ongoing projects in their respective communities during the vacation and

1. outline the various engineering skills and competencies required to solve such a problem or complete the project or
2. outline their own solutions to the identified problems and present a written, oral or power point presentation.

GESI related issues: Addressing gender equality and social inclusion in the context of talk-for-learning is crucial to creating an equitable and respectful learning environment.

Inclusive language: Use gender-neutral language and avoid assumptions about students' identities.

Diverse perspectives: Incorporate diverse voices and perspectives in the class. Use examples, case studies, and materials that reflect different cultures, experiences, and identities.

Safe environment: Foster an environment where students feel safe discussing sensitive topics related to gender, identity, and social issues. Establish guidelines for respectful dialogue and intervene if any harmful behaviours occur.

Equitable participation: Be mindful of power dynamics in discussions. Ensure that marginalised voices have an equal opportunity to contribute and are not silenced by dominant groups.

Experiential learning and GESI-related issues: There are several considerations to keep in mind:

Equity and access: Experiential learning opportunities should be accessible to all individuals, regardless of their gender, social background, or other characteristics. Efforts should be made to ensure that marginalised groups are not excluded from these opportunities due to systemic barriers.

Representation: Experiential learning activities should strive to represent diverse voices and perspectives. This includes having diverse role models, mentors, and facilitators who can serve as relatable examples for learners from different backgrounds.

Gender awareness: Experiential learning activities can challenge traditional gender roles and biases. Educators should be aware of gender stereotypes and ensure that activities promote gender equality and challenge harmful norms.

GESI-related issues in collaborative learning: In collaborative learning settings, several GESI-related issues may arise.

Addressing GESI-Related Issues:

Inclusive group formation: Ensure diverse representation in groups to avoid isolation of marginalised individuals.

Diverse content: Curate learning materials that reflect a variety of perspectives, cultures, and identities.

Encourage participation: Create an environment where all voices are heard and respected, and where quieter individuals are given opportunities to contribute.

Sensitive facilitation: Facilitators should be aware of power dynamics and intervene if any participant is being marginalised or excluded.

Flexible assessment: Offer a variety of assessment methods to accommodate different learning styles and abilities.

Open communication: Encourage open discussions about GESI-related issues and provide a platform for students to share their experiences and concerns.

Accessibility: Ensure that learning resources and spaces are accessible to all students, regardless of their backgrounds or abilities.

Building on what others say: Other groups add to the content presented by each group in a respectful manner. Groups should be encouraged to tolerate others' views.

Encourage learners to cooperate and respect each other's views

Key Assessment

Level 1

1. Match each engineering discipline with its corresponding description.
   A. Civil Engineering
   B. Mechanical Engineering
   C. Electrical Engineering
   D. Chemical Engineering
   E. Aerospace Engineering
   a. The branch of engineering that deals with the design and construction of physical and natural structures, such as buildings, roads, bridges, and dams.
   b. Focuses on the design and development of aircraft, spacecraft, satellites, and related technologies.
   c. Involves the application of principles of scientific principles to design and operate processes that convert raw materials into useful products.
   d. Concerned with the study, design, and production of systems and processes, such as engines, machines, and thermal devices.
   e. Focuses on the study and application of electricity, electronics, and electromagnetism in various systems and devices.

Level 2

1. Explain the differences between aerospace engineering and aeronautical engineering and discuss the kinds of projects associated with each.
2. List ten (10) different works observable within your school environment and discuss the role of various engineering professionals in accomplishing those projects.
3. Classify various engineering occupational disciplines and their specific contribution to solving your community problems.

Level 3

1. How can computer engineering, electrical engineering, and civil engineering work together to build sustainable, connected urban environments?
2. What are some of the emerging engineering disciplines and what roles are they expected to perform in solving global problems.
3. Consider an ongoing engineering project and discuss the collaborative contributions of various engineering professionals in accomplishing the project.

Week 2

Learning Indicator(s):

1. *Establish the interdependencies across the engineering disciplines*
2. *Outline the common skill set required by the respective engineering disciplines*
3. *Explain the unique knowledge requirement of the disciplines and the associated engineering careers*

Theme or Focal Area 1:

Interdependencies across engineering disciplines are crucial for delivering comprehensive and successful projects. Engineering fields often overlap and collaborate to create complex systems and technologies. Here are some common interdependencies and references that highlight these relationships:

1. **Mechanical Engineering and Electrical Engineering:** The design of electromechanical systems, robotics, and mechatronics requires collaboration between mechanical and electrical engineers.

Figure 9: A picture of an electrical and mechanical engineers at work

Source: shutterstock.com, url: https://shorturl.at/EGHJ7, [accessed: 21.03.2024]

2. **Civil Engineering and Environmental Engineering:** Civil engineers design infrastructure while considering environmental impacts and sustainability. Environmental engineers contribute to waste management, water treatment, and pollution control in civil projects.

Figure 10: A picture of a civil and environmental engineers

Source: dreamstime.com, url: https://rb.gy/qv750q, [accessed: 21.03.2024]

3. **Chemical Engineering and Materials Engineering:** Chemical engineers work with materials engineers to design and optimise processes for manufacturing and modifying chemicals and materials.

Figure 11: A picture of a chemical and material science engineers

Source: shuterstock.com, url: https://shorturl.at/lrA37, [accessed: 21.03.2024]

4. **Aerospace Engineering and Computer Engineering:** Aerospace engineers collaborate with computer Engineers for flight control systems, aeroplane black boxes, simulations, and data analysis in aerospace applications.

Figure 12: A picture of an Aerospace and Computer Engineer.

Sources: shutterstock.com, url: https://shorturl.at/rwUV8, [accessed: 21.03.2024]

5. **Biomedical Engineering and Software Engineering:** Biomedical engineers work with software engineers to develop medical devices, imaging systems, and healthcare software. Examples are (Magnetic Resonant Imaging (MRI) Scanner, heart pacemaker, insulin pumps, etc.

Figure 13: A picture of a Biomedical and Software Engineer.

Source: gettyimages.com, url: https://shorturl.at/gjxH8, [accessed: 21.03.2024]

6. **Industrial Engineering and Business Management:** Industrial engineers often partner with business managers to optimise processes, supply chains, and operations.

Figure 14: A picture of an industrial and business management engineer

Source: istokephoto.com, url: https://shorturl.at/nDLQ0, [accessed: 21.03.2024]

7. **Electrical Engineering and Computer Engineering:** These fields collaborate on the design of integrated circuits, computer hardware, and embedded systems.

Figure 15: A picture of an electrical and computer engineer

Source: istokephotos.com, url: https://shorturl.at/hAFQ5, [accessed: 21.03.2024]

8. **Mechanical Engineering and Aerospace Engineering:** Both fields contribute to the design of aircraft, spacecraft, and propulsion systems.

Figure 16: A picture of a mechanical and aerospace engineer

Source: gettyimages.com, url: https://shorturl.at/cnJWY, [accessed: 21.03.2024]

9. **Electrical Engineering and Renewable Energy Engineering:** Electrical engineers play a significant role in the design and optimisation of renewable energy systems like solar and wind power.

Figure 17: A picture of an electrical and renewable energy engineers

Source: gettyimages.com, url: https://shorturl.at/krw01, [accessed: 21.03.2024]

Learning Task:

1. Discuss the concept of collaboration in executing a project.
2. Discuss the concept of interdisciplinarity among various engineering disciplines in undertaking a project or solving a given societal problem.
3. Examine the difficulty associated with one professional solving a problem alone or undertaking a project alone.
4. Examine the creation of a large-scale infrastructure project, such as a suspension bridge. Explain the coordination between structural, geotechnical, geomatic, architectural, and transportation engineers to ensure the bridge's stability, safety, and functional design.
5. Discuss how computer engineers, software developers, and data scientists collaborate to design and implement a smart home automation system. Highlight the integration of hardware and software components and how this collaboration enhances the user experience.
6. Imagine designing a new amusement park ride that involves both mechanical and electrical components. Elaborate on the synergistic efforts of engineers from these disciplines, considering factors such as safety, motion control, and sensory experiences.
7. Explore the development of a cutting-edge medical prosthetic. Describe the teamwork between mechanical engineers, bioengineers, and medical professionals, emphasising how their combined knowledge results in innovative solutions for improved patient outcomes.

Theme or Focal Area 2:

Engineering is a vast and diverse field that encompasses various specialised disciplines. Each engineering discipline focuses on specific areas of technology, science, and problem-solving. While each engineering discipline has its unique requirements, several core skills are universally valuable across most engineering disciplines. The importance of engineering skills cannot be overstated, as they form the foundation upon which engineers build their careers and contribute to advancements in various industries.

1. **Mathematics and Science Foundation:** A strong foundation in mathematics and science is the bedrock of engineering education. Mathematics provides the language of engineering, enabling engineers to model, analyse, and solve complex problems. Science, on the other hand, offers the fundamental understanding of natural phenomena necessary for designing and optimising engineering solutions. A thorough grounding in these subjects equips engineers with the tools to tackle real-world challenges effectively.
2. **Technical Competence:** Technical competence is the cornerstone of engineering expertise. Engineers must master the fundamental principles, theories, and concepts relevant to their chosen field. This competence empowers them to design, create, and implement innovative solutions that address specific challenges. In today's rapidly evolving technological landscape, continuous learning is paramount to staying abreast of emerging technologies and maintaining technical relevance.
3. **Problem Solving and Critical Thinking:** Engineering is, at its core, about solving problems. Problem-solving and critical thinking skills enable engineers to dissect complex challenges, identify viable solutions, and make informed decisions. Teaching students various problem-solving methodologies and providing hands-on experiences through projects instils the ability to approach problems systematically and creatively.
4. **Analytical and Quantitative Skills:** Analytical and quantitative skills are integral to engineering decision-making. Engineers must be adept at collecting, analysing, and interpreting data to make informed choices. Introducing statistical analysis equips them to evaluate risks, optimise designs, and make evidence-based decisions that contribute to successful project outcomes.
5. **Communication Skills:** Effective communication is vital for engineers to convey ideas, collaborate with colleagues, and present technical information to various audiences. Clear and concise communication, both written and oral, ensures that engineering concepts are understood and implemented accurately. Providing opportunities for students to practice communication enhances their ability to convey complex ideas effectively.
6. **Collaboration and Teamwork:** Engineering projects are rarely solitary endeavours; they often require collaboration among interdisciplinary teams. Teaching students how to work effectively in teams fosters diverse perspectives, encourages the exchange of ideas, and enhances problem-solving capabilities. Group projects provide valuable experiences in managing conflicts, delegating tasks, and achieving common goals.
7. **Creativity and Innovation:** Innovation drives engineering advancements, and cultivating creativity is essential. Engineers must think beyond conventional solutions and explore new possibilities. Encouraging students to embrace unconventional ideas, experiment with different approaches, and employ design thinking methodologies empowers them to develop novel solutions that push the boundaries of traditional engineering.
8. **Ethical and Professional** Responsibilities: Engineers hold a significant responsibility to society, safety, and the environment. Discussing ethical considerations, sustainability, and social impact equips engineers with a holistic perspective on their work, emphasising integrity, ethics, and professionalism ensures that engineers contribute ethically and responsibly to the betterment of society.
9. **Project Management and organisation:** Engineering projects demand effective project management skills. Introducing students to project management concepts, such as planning, organising, and time management, prepares them to lead projects successfully. Meeting deadlines, managing resources, and ensuring project success become achievable goals.

10. **Adaptability and Lifelong Learning:** The engineering landscape evolves rapidly due to technological advancements. Engineers must embrace adaptability and commit to lifelong learning to remain relevant. Encouraging a growth mindset and providing resources for Continuing Professional Development (CPD)empowers engineers to stay current, adapt to change, and drive innovation throughout their careers.

Learning Task

1. Explore the 21st century skills that are critical to the engineering profession.
2. Explain the concept of teamwork and collaboration in engineering projects.
3. Discuss how crucial adaptability is for engineers?
4. Have learners create a poster presentation of the critical skills required by engineers of various fields.
5. Use a table to compare two engineering disciplines in terms of their common skill requirements.
6. Analyse the role of critical thinking skills in the field of engineering.
7. Evaluate the impact of technological advancements on the evolving skill set required of engineers.
8. Describe how communication considerations play a role in the skill set of engineers.
9. Guide learners to discuss how innovation and creativity have helped brought comfort and convenience to society.

Theme or Focal Area 3:

Engineering disciplines encompass a wide array of specialised fields that apply scientific and mathematical principles to design, innovate, and create solutions for real-world problems. Each engineering discipline has its own unique knowledge requirements that are shaped by the specific challenges and applications it addresses. This learning indicator provides a brief overview of some prominent engineering disciplines and their unique knowledge requirements:

1. **Mechanical Engineering:** Mechanical engineers focus on designing and analysing mechanical systems, including machines, structures, and devices. Their unique knowledge requirements include understanding mechanics, materials science, thermodynamics, and fluid dynamics. They also need expertise in computer-aided design (CAD) software and manufacturing processes.
2. **Electrical Engineering:** Electrical engineers deal with electrical systems, electronics, and electromagnetism. They require knowledge in circuit analysis, control systems, digital signal processing, and power distribution. Additionally, they need expertise in programming languages and software tools for designing and simulating electrical systems.
3. **Civil Engineering:** Civil engineers specialise in designing and managing infrastructure projects such as buildings, bridges, roads, and water systems. Their unique knowledge requirements include structural analysis, geotechnical engineering, transportation engineering, and environmental engineering.
4. **Chemical Engineering:** Chemical engineers focus on processes involving chemicals, materials, and energy. They need knowledge in thermodynamics, chemical kinetics, transport phenomena, and process control. Chemical engineers often work in industries such as pharmaceuticals, petrochemicals, and food processing

5. **Aerospace Engineering:** Aerospace engineers specialise in designing aircraft, spacecraft, and related systems. Their unique knowledge requirements encompass aerodynamics, propulsion systems, orbital mechanics, and structural analysis for extreme conditions
6. **Biomedical Engineering:** Biomedical engineers merge biology and engineering to develop medical technologies and equipment. Their unique knowledge requirements involve biology, physiology, medical imaging, biomaterials, and instrumentation.
7. **Computer Engineering:** Computer engineers focus on the design and development of computer systems and networks. Their unique knowledge requirements include digital systems design, microprocessors, computer architecture, and software engineering principles.

Learning Tasks

1. Give an example of a unique knowledge requirement for the various engineering careers.
2. Discuss how the unique knowledge requirements for engineering careers differ compared with other professions?
3. Explain how the unique knowledge requirements of engineering careers relate to the diverse fields within engineering, such as civil engineering, mechanical engineering, and electrical engineering.
4. Compare and contrast the unique knowledge requirements of engineering careers with those of professions like medicine or law. How do these requirements shape the educational path and training for each field?
5. Discuss the role of continuous learning in meeting the evolving unique knowledge requirements of engineering careers. Provide examples of how engineers can stay updated in their rapidly changing field.
6. Elaborate on the ethical considerations related to the unique knowledge requirement in engineering careers. How can engineers ensure their specialised knowledge is used responsibly for the benefit of society?

Pedagogical Exemplars

Refer to week 1 for the pedagogical exemplars.

Key Assessment

Level 1

Explain the roles to be played by various engineering disciplines in the following projects from start to finish; construction of a community library, a bridge linking your school to the town/city.

Level 2

Explain how different engineering occupations and other professionals collaborate to produce a community water project, bottled water and sachet water.

Level 3

1. Explain how different engineering disciplines collaborate to design and develop a complex product, like a smartphone. Identify specific roles that engineers from various disciplines would play in this process.

2. Compare and contrast the contributions of mechanical, electrical, and software engineers in the development of an automated manufacturing system. How do their expertise and responsibilities interconnect to ensure the system's success?
3. Imagine you are designing a sustainable city. Describe the collaborative efforts required among civil, telecommunication, environmental, and architectural engineers to ensure the city's infrastructure is efficient and environmentally friendly. Provide examples of interdependent decisions they might make.

Level 4

1. Research a renewable energy project, like a solar power plant. Detail the collaboration between civil, electrical, and environmental engineers, highlighting the challenges they might face and the solutions they develop through cross-disciplinary cooperation.
2. Investigate the process of creating a new medical device, such as an MRI machine. Discuss the critical cooperation between biomedical, electrical, and materials engineers, and explain how each discipline's input affects the final product.
3. Illustrate how aerospace engineers, alongside materials scientists and propulsion engineers, work together to develop a new aircraft. Analyse the ways their areas of expertise are interconnected and necessary for achieving flight safety and efficiency.
4. Create an essay exploring the common skills set, and unique knowledge requirements for at least two engineering disciplines.

Section 1 Review

1. Would learners be able to classify the various engineering occupational disciplines?
2. Can learners explain the contributions of each of the engineering disciplines in solving societal problems?
3. Would learners be able to establish the interdependencies across the engineering disciplines?
4. Can learners explain the common skill set required by the respective engineering disciplines?
5. Would learners be able to explain the unique knowledge requirement of the various disciplines?

Further Reading

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SECTION 2: HEALTH AND SAFETY

Strand: **Engineering Practice**

Sub-strand: Health and Safety in Engineering Practice

Learning Outcome: *Examine the causes and effects of accidents in engineering practice*

Content Standard: Demonstrate an understanding of health and safety risks in engineering

INTRODUCTION AND SECTION SUMMARY

Engineering accidents, also known as industrial accidents or technological accidents, are incidents that occur due to failures or errors in the design, operation, maintenance, or management of engineering systems and processes. Accidents in engineering practice can have far-reaching consequences, ranging from devastating injuries and loss of life to significant financial and reputational damages. The causes of these accidents often involve a combination of human, organisational, and technical factors. Safety is everyone's responsibility. Whether you are a hobbyist or a professional, it is crucial to prioritise safety in any workshop setting to prevent accidents, injuries, and potential hazards. This section emphasises the importance of workshop safety, the potential hazards associated with tools and machinery, and the responsibility of individuals to prioritise their safety and the safety of others in the workshop environment. The lessons in this section equip learners to demonstrate general competence in the use of both hand and power tools while following proper health and safety protocols. As a teacher, keep in mind that safety is of utmost importance when working with tools, so always make sure to refer to the specific guidelines and instructions provided by the tool manufacturer and your local safety regulations.

The weeks covered by the section are:

Week 3: Health and Safety in Engineering Practice

Week 4: Safety in Handling Tools and Machinery

SUMMARY OF PEDAGOGICAL EXEMPLARS

Learners may face multiple forms of discrimination due to their intersecting identities (e.g., gender, ethnicity, socio-economic status, etc.). Gender in particular may limit the participation of females in workshop practice and the handling of tools and machinery that are understood to be stereotypically a male-dominated profession. Cultural differences can affect learners' communication styles and responses during talk-for-learning activities. Thus, as a teacher, you should consider using a variety of teaching methods and techniques that encourages the participation of all learners irrespective of their background, gender and learning abilities. Groupings for the teaching and learning activities should create opportunities for all learners, especially females, to handle tools and machinery in the workshop practice. Consider experiential learning approaches such as field visit to an ongoing engineering project to experience safety practices. Also consider case study of engineering or industrial accidents to draw valuable lessons. Moderate discussions when learners share their experiences and consider question-and-answer strategy as a means of inclusion. Teachers need to be sensitive to these variations and foster an inclusive environment that respects and appreciates diverse cultural perspectives.

ASSESSMENT SUMMARY

Various categories of assessment modes should be considered to afford all categories of learners the opportunity to express their understanding of the major themes in the section. Provide examples of high-profile engineering accidents that have happened in the past decade and let learners explain each case. Present learners with scenarios describing engineering accidents and ask them to identify the primary contributing factors. Learners can also be encouraged to outline their own solutions to the identified problems and present a written, oral or power point presentation in class; which can contribute to learners' summative assessmen*t*.

Week 3

Learning Indicator(s):

1. *List accidents that occur in engineering practice*
2. *Identify the causes of accidents in engineering practice and explain their effects*

Theme or Focal Area 1:

Engineering accidents, also known as industrial accidents or technological accidents, are incidents that occur due to failures or errors in the design, operation, maintenance, or management of engineering systems and processes.

Some examples of accidents that can happen in engineering practice:

1. ***Structural Failures:*** Collapse of buildings, bridges, dams, or other structures due to design flaws, inadequate construction, or unforeseen loads.

Figure 18: A picture of a structural failure

2. ***Industrial Accidents:*** Accidents in manufacturing plants, chemical plants, refineries, or factories that can lead to fires, explosions, or toxic releases.

Figure 19: A picture of an industrial accident

3. ***Electrical Accidents:*** Electrical fires, electrocutions, or equipment malfunctions resulting from faulty wiring, inadequate grounding, or human error.

Figure 20: A picture of an electrical accident

4. ***Mechanical Failures:*** Malfunctioning machinery or equipment that leads to injuries, such as in factories, construction sites, or transportation vehicles.

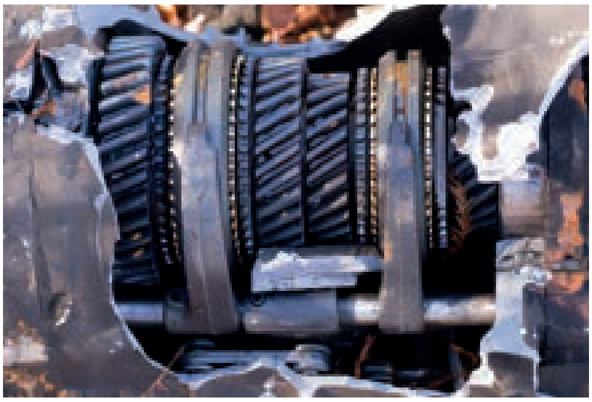

Figure 21: A picture of a mechanical failure of a machine

5. ***Pipeline Explosions:*** Accidents involving gas or oil pipelines due to corrosion, inadequate maintenance, or external factors like digging.

Figure 22: A picture of a pipeline explosions

6. ***Aviation Accidents:*** Plane crashes or incidents involving aircraft due to mechanical failure, pilot error, or adverse weather conditions.

Figure 23: A picture of an aircraft involved in an accident

7. ***Maritime Accidents:*** Shipwrecks, collisions, or capsizing of vessels due to navigation errors, equipment failures, or storms.

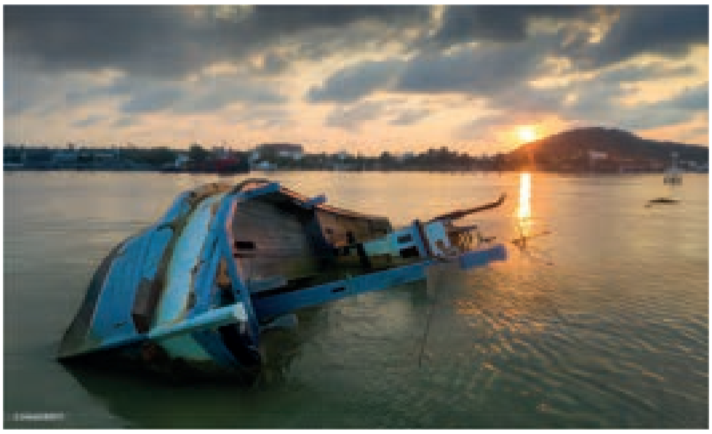

Figure 24: A picture of a capsizing vessel

8. ***Train Derailments:*** Accidents involving trains derailing due to track defects, signal failures, or human mistakes.

Figure 25: A picture of a train derailing

9. ***Mining Accidents:*** Incidents in mines related to cave-ins, explosions, or gas leaks, are often caused by safety violations or inadequate procedures.

Figure 26: A picture of a mining accident

10. ***Construction Site Accidents:*** Falls, collapses, or equipment-related incidents at construction sites due to poor safety practices or negligence.

Figure 27: A picture of a collapsed building

11. ***Nuclear Accidents:*** Disasters at nuclear power plants resulting from reactor failures, coolant leaks, or natural disasters.

Figure 28: A picture of a nuclear accident

12. ***Oil Rig Accidents:*** Explosions, fires, or oil spills on offshore drilling platforms due to equipment failures or human errors.

Figure 29: A picture of an oil rig accident

13. ***Chemical Accidents:*** Accidental releases or leaks of hazardous chemicals in laboratories, plants, or storage facilities.

Figure 30: A picture of a chemical accident

Source: istockphoto.com, url: https://shorturl.at/cgxEI, [accessed: 22.03.2024]

14. ***Transportation Accidents:*** Accidents involving automobiles, buses, or trains due to mechanical failures, human error, or adverse weather conditions.

Figure 31: A picture of automobiles involved in an accident

15. ***Environmental Accidents:*** *Accidents that result in environmental damage, such as oil spills, toxic waste releases, or chemical contamination.*

Figure 32: A picture of an environmental accident

This is how engineers typically apply their knowledge in the aftermath of engineering accidents:

1. **Root Cause Analysis:** Engineers are skilled at conducting root cause analysis, which involves examining all the contributing factors that led to the accident.
2. **Risk Assessment:** Engineers are also skilled at conducting risk assessments; in which they determine the source of risk, their probability of occurrence, their severity levels, etc and use such information to prioritise addressing the risks based on the impact and urgency.
3. **Failure Analysis:** Engineers use their knowledge of materials, structural integrity, and system behaviour to analyse the failed components or systems involved in the accident.
4. **Computer Simulations and Modelling:** Engineers use computer simulations and modelling tools to recreate the accident scenario virtually. By inputting the known parameters and variables, they can test different scenarios and assess the possible outcomes.
5. **Lessons Learned and Best Practices:** Engineers contribute to compiling a report detailing the findings of the accident investigation. They identify the lessons learned and suggest best practices to avoid similar accidents in the future.
6. **Safety and Risk Assessments:** Engineers play a critical role in performing safety and risk assessments for existing and new designs.
7. **Design Improvements:** Based on the findings of the accident investigation, engineers work on redesigning components, systems, or processes to eliminate the identified weaknesses.

8. **Regulatory Compliance:** Engineers work closely with regulatory bodies to ensure that their designs and solutions comply with safety standards and regulations.
9. **Training and Education:** Engineers play a vital role in educating and training other engineers, technicians, and personnel involved in the industry.

Learning Task

1. Discuss the role of human error in engineering accidents and how it can be minimised.
2. Compare and contrast the safety protocols in two different engineering industries to highlight potential differences and similarities in accident prevention.
3. Analyse the root causes of a specific engineering accident and propose potential measures that could have prevented it.
4. Conduct a risk assessment for a given project.
5. Guide learners to conduct individual research on major engineering accident and make presentations in class.

Theme or Focal Area 2:

Accidents in engineering practice can have far-reaching consequences, ranging from devastating injuries and loss of life to significant financial and reputational damages. The causes of these accidents often involve a combination of human, organisational, and technical factors.

Common causes of accidents in engineering practice and their effects.

1. **Human Error:** Human error is one of the leading causes of accidents in engineering. It can result from fatigue, lack of attention, poor training, or even intentional violations of safety protocols. The effects of human error can vary widely, from minor mistakes that cause inconvenience or minor injuries to major incidents that lead to significant damage, injuries, or loss of life.
2. **Equipment Malfunction or Failure:** Defects, malfunctions, or failures in engineering equipment can lead to accidents. Whether it's a structural failure, electrical malfunction, or a mechanical breakdown, the effects can be severe, causing injuries, property damage, and operational disruptions.
3. **Inadequate Maintenance:** Failure to properly maintain engineering equipment and infrastructure can lead to accidents over time. Regular maintenance is crucial to ensure that systems function as intended and that potential issues are identified and addressed before they escalate into accidents. The effect of inadequate maintenance can result in unexpected failures, safety hazards, and costly repairs.
4. **Poor Design:** Engineering projects with flawed designs can lead to accidents. These flaws may not be apparent during initial testing or implementation, but they can surface later during operation, causing accidents. Poor design can compromise the safety and efficiency of structures, systems, or processes, leading to potential disasters.
5. **Environmental Factors:** External factors, such as severe weather conditions (e.g., hurricanes, earthquakes, floods) or geological instability, can lead to accidents in engineering projects. These natural events can cause damage to structures, disrupt operations, and put people at risk.
6. **Inadequate Risk Assessment:** Insufficient or improper risk assessment before starting an engineering project can lead to unforeseen hazards. Engineers must identify and evaluate potential risks to develop appropriate safety measures. Failure to do so can result in accidents that might have been preventable.

7. **Lack of Safety Procedures:** The absence or lax enforcement of safety protocols in engineering practice can significantly increase the likelihood of accidents. Proper safety procedures and guidelines are essential to protect workers, equipment, and the environment from harm.
8. **Communication Breakdown:** Miscommunication or poor communication between different stakeholders involved in an engineering project can lead to misunderstandings, errors, or overlooked safety concerns. Effective communication is crucial for ensuring that everyone is aware of potential risks and safety measures.
9. **External Interference:** Accidents can also occur due to interference from external factors, such as third-party activities, accidents in neighbouring areas, or security breaches. These can disrupt operations, damage equipment, and compromise safety measures.

Engineers apply their knowledge and skills to thoroughly investigate accidents, propose design improvements, assess risks, comply with regulations, implement maintenance and inspection protocols, use simulation and modelling tools, promote continuous improvement, provide training, and collaborate with various experts to prevent engineering accidents and enhance safety in their projects and industries.

How engineers identify the causes of accidents in engineering practice:

1. Structural Failure: A bridge collapse

Engineers will conduct a thorough inspection of the collapsed bridge, and collect data on the materials used, construction methods, and maintenance history. They may use non-destructive testing techniques like ultrasonic testing or X-ray to evaluate the integrity of critical components. Finite element analysis and computer simulations might be used to understand how external factors such as weather conditions and traffic loads contributed to the failure.

2. Chemical Plant Accidents: A chemical release or explosion

An engineer will analyse the process data leading up to the accident and review the design specifications, operating procedures, and safety systems of the plant. They might recreate the accident scenario using computer simulations or scale models to understand the sequence of events. Detailed chemical analysis can help identify the presence of hazardous substances and their reaction pathways during the accident.

3. Aviation Accidents: An airplane crash

A team of aerospace engineers will examine the wreckage, flight data recorders (black boxes), and maintenance records of the aircraft. They'll recreate the flight path and conditions during the accident using flight simulators and conduct computational fluid dynamics (CFD) analyses to understand the aerodynamic behaviour. Human factors experts will also be involved to investigate potential pilot error or cockpit design issues.

Learning Task

1. Discuss the different types of accidents that can occur in engineering practice, such as structural failures, equipment malfunctions, and electrical hazards, observable within the school environment.
2. Discuss the different types of precautions that can be taken to avoid accidents identified in (1), such as safety procedures.
3. Discuss the importance of safety measures and risk mitigation strategies in preventing accidents.
4. Describe the role of organisational culture in accident prevention within engineering companies. Provide examples to support your explanation.
5. Examine the relationship between risk assessment and accident prevention in engineering projects. How can a thorough risk assessment mitigate potential hazards?
6. Discuss the ethical implications for engineers and project managers when accidents occur due to negligence or oversight. Suggest measures to avoid such situations in the future.
7. Discuss accidents that have occurred in major engineering projects around the country, precautions taken to avoid future accidents as well as other safety measures, risk and mitigation strategies undertaken to prevent accidents.
8. Watch video documentary of major accidents that have occurred around the world, precautions taken to avoid future accidents as well as other safety measures, risk and mitigation strategies undertaken to prevent accidents.
9. Guide learners to conduct a risk assessment for a given project that is ongoing in their communities.

Pedagogical Exemplars

1. **Experiential Learning**: Learners visit an ongoing engineering project site to learn about the safety measures put in place to avoid accidents.
2. **Problem-Based-Learning**: Learners visit an engineering or industrial accident scene to learn about causes and mitigation of accidents.
3. **Experiential Learning**: Learners carry out a risk assessment for an activity or project within the school or local community to learn about identifying hazards, assessing the risks and identifying the mitigation that should be put in place.
4. **Case Study**: Learners discuss a major historical engineering accident, such as Chenobyl disaster to learn all the dimensions of safety in engineering practice.
5. **Enquiry-Based Learning**: Learner's research into major historical industrial, military and civilian disasters and make presentations in class.
6. **Managing talk-for-learning:** In a moderated discussion, learners share their experiences of accidents they have been involved in or have seen. The experience sharing should cover the cause of the accident, the effect(s) and what could have prevented it. Further to this, learners list potential accidents in engineering practice.
7. **Building on what others have said:** Other groups add to the content presented by each group in a respectful manner. Groups should be encouraged to tolerate others' views.

Key Assessment

Level 1 Recall:

1. What is an engineering accident?
2. Give six (6) examples of accidents that occur in engineering practice.
3. State four (4) safety precautions you will observe as an engineer to avoid accidents
4. What is an accident in the context of engineering practice?
5. Define engineering practice and its significance in various industries.
6. Can you name a few common industries where engineering accidents may occur?
7. What are the potential consequences of accidents in engineering practice?
8. Describe some factors that may contribute to accidents in engineering.

Level 2 Skills of conceptual understanding:

1. Provide examples of high-profile engineering accidents that have happened in the past decade and briefly explain each case.
2. Describe the role of human error in engineering accidents and how it can be minimised.
3. Compare and contrast the safety protocols in two different engineering industries to highlight potential differences and similarities in accident prevention.

Level 3 Strategic thinking:

1. Mention the root causes of a specific engineering accident and propose potential measures that could have prevented it.
2. Evaluate the impact of an engineering accident on public perception and trust in the industry and suggest strategies for restoring confidence.

Week 4

Learning Indicator(s):

1. *Explain the health and safety protocols associated with basic workshop tools/machinery*
2. *Demonstrate the use of both hand and power tools according to proper health and safety protocols*

Theme or Focal Area 3:

Safety is everyone's responsibility. Whether you are a hobbyist or a professional, it's crucial to prioritise safety in any workshop setting to prevent accidents, injuries, and potential hazards. This learning indicator emphasises the importance of workshop safety, the potential hazards associated with tools and machinery, and the responsibility of individuals to prioritise their safety and the safety of others in the workshop environment.

Below are some essential health and safety protocols associated with basic workshop tools and machinery:

1. **Personal Protective Equipment (PPE)**: Always wear appropriate PPE, including safety goggles, ear protection, gloves, and closed-toe shoes. Depending on the task, additional equipment such as a dust mask or a face shield may be necessary.

Figure 33: A picture of a man wearing PPE

2. **Proper Training and Familiarisation:** Ensure that all users have received proper training on the safe operation of each tool and machinery. Never operate a tool or machine if you are not familiar with its use.
3. **Work Area Safety:** Keep the workshop clean and organised to minimise hazards and prevent tripping or slipping accidents. Ensure adequate lighting to see the work area and the tool controls clearly.
4. **Machine Inspection and Maintenance:** Regularly inspect tools and machinery for any damage or malfunction before use. Follow the manufacturer's maintenance schedule and guidelines to ensure proper functioning.

5. **Safe Handling and Operation:** Read and follow the instruction manuals and safety guidelines provided by the manufacturer for each tool. Always use the appropriate tool for the task at hand. Don't use a tool or machine for a purpose it is not intended for.
6. **Electrical Safety:** Keep cords and cables away from sharp edges or moving parts to prevent damage. Check cords for wear and tear, and never use damaged cords.
7. **Guarding and Safety Features:** Ensure all safety guards and features on the machinery are in place and functional. Do not bypass or disable safety mechanisms.
8. **Tool Maintenance and Sharpness:** Keep cutting tools sharp and well-maintained to prevent accidents caused by using dull tools.
9. **Handling Materials Safely:** Use clamps or other appropriate methods to secure the workpiece during cutting or shaping operations. Avoid hand-feeding materials into moving machinery.
10. **Fire Safety:** Keep a fire extinguisher and a first aid kit readily available in the workshop. Know the location of emergency shut-off switches for machinery.
11. **Proper Body Positioning:** Stand and position yourself correctly to maintain balance and stability while using tools and machinery.
12. **No Horseplay:** Strictly enforce a no-horseplay policy in the workshop to prevent distractions and potential accidents.

Figure 34: No Horseplay signs

13. **Emergency Procedures**: Know the workshop's emergency procedures, including how to shut off power and what to do in case of an accident or injury.
14. **Chemical Safety:** Store and handle hazardous chemicals properly in designated areas, following safety data sheets and guidelines.
15. **Supervision:** Ensure that novice or inexperienced individuals are supervised when using workshop tools and machinery.

By strictly adhering to these health and safety protocols, the risk of accidents and injuries in a workshop setting can be significantly reduced, creating a safer working environment for all.

Some Machines Safety protocols.

1. **Machine Guarding:** Engineers design and implement machine guarding systems to prevent operators from coming into direct contact with hazardous moving parts of machinery.
2. **Safety Interlocks:** Engineers often incorporate safety interlock systems into workshop tools and machinery. These systems ensure that certain safety conditions are met before the machine can operate.
3. **Emergency Stop Systems:** Engineers equip workshop machinery with emergency stop systems to immediately halt operations in case of an emergency.

Learning Tasks

1. Discuss with learners the procedure for inspecting and maintaining workshop tools to ensure they are in safe working condition.
2. Engage learners in a discussion on why regular maintenance is crucial.
3. Describe the appropriate handling and storage practices for hazardous materials commonly used in workshops, such as paints, solvents, and adhesives.
4. Identify and explain the safety features and mechanisms found in basic workshop tools and machinery that are designed to protect users from potential accidents.
5. Discuss the importance of having a clear and organised workshop layout to enhance safety. Provide examples of how tools and equipment should be arranged for efficient and safe operations.
6. Visit the workshop with your learners and demonstrate simple safety in handling tools and machinery.
7. Have learners do posters on health and safety in a workshop space.
8. Watch videos on accidents occasioned by failure in adhering to safety procedures.

Theme or Focal Area 4:

General demonstration of using both hand and power tools while following proper health and safety protocols. Keep in mind that safety is of utmost importance when working with tools, so always make sure to refer to the specific guidelines and instructions provided by the tool manufacturer and your local safety regulations.

Power tools

Hand tools

Figure 35: Portable power tools and hand tools

Scenario: Using a hand drill and a power saw

1. **Hand Drill:**

Step 1: Safety Gear and Workspace Setup

- Put on appropriate personal protective equipment (PPE) such as safety glasses, hearing protection, and gloves.
- Choose a well-ventilated and well-lit workspace.

Step 2: Inspect the Hand Drill

- Ensure the drill is in good condition, with no frayed cords or damaged parts.

- Check that the chuck is securely holding the drill bit.

Step 3: Secure the Workpiece

- Clamp the workpiece securely to a stable surface to prevent movement while drilling.

Step 4: Drill Bit Selection

- Choose the appropriate drill bit size for the task.

Step 5: Drilling

- Hold the drill with a firm grip, keeping your hands away from the rotating parts.
- Align the drill bit with the desired hole location.
- Apply gentle pressure and start the drill at a low speed.
- Gradually increase the speed while maintaining control.

Figure 36: A picture of a Hand drill

2. **Power Saw (Circular Saw):**

Step 1: Safety Gear and Workspace Setup

- Wear safety glasses, hearing protection, gloves, and a dust mask.
- Set up your workspace with adequate lighting and ventilation.

Step 2: Inspect the Circular Saw

- Ensure the saw's blade is in good condition and properly tightened.
- Check that the safety guard moves smoothly.

Step 3: Secure the Workpiece

- Place the workpiece on a stable surface and secure it with clamps if needed.

Step 4: Saw Blade Selection

- Choose a blade appropriate for the material you're cutting.

Step 5: Cutting

- Hold the saw with both hands, one on the handle and one on the auxiliary handle.
- Start the saw away from the workpiece, then gently bring it into contact with the material.
- Allow the blade to reach full speed before making the cut.
- Maintain a steady pace and avoid forcing the saw.

Figure 37: A picture of an engineer using power saw

General Safety Tips:

1. Always read the user manual for each tool before use.
2. Keep your workspace clean and organised to prevent tripping hazards.
3. Disconnect power tools when changing accessories or adjusting.
4. Keep bystanders away from your work area.
5. Never wear loose clothing or jewellery that might get caught in the tools.

If you're not sure how to use a tool safely, seek guidance from a knowledgeable person or take a training course.

Learning task

1. Discuss the importance of maintaining tools in good working condition for both safety and efficiency.
2. Provide examples of maintenance tasks that should be performed regularly on hand and power tools.
3. Role-play a scenario where a classmate is about to use a power tool incorrectly and unsafely. Describe how you would approach them and explain the correct way to use the tool while emphasising safety protocols.
4. Investigate and list the types of personal protective equipment (PPE) that should be worn when using hand and power tools. Explain why each piece of PPE is necessary.
5. Have learners try out various PPEs in the workshop.
6. Analyse a case study of a workplace accident involving hand or power tools. Identify the factors that contributed to the accident and suggest measures that could have prevented it from occurring.
7. Discuss a sample safety design in a workspace.
8. Discuss the preparation of safety manual.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** From videos and or pictures shared, learners identify workshop tools and machinery. In pairs, learners think and share with the whole class uses of such equipment

2. **Managing talk-for-learning:** In a moderated discussion, learners outline their perceived health and safety protocols for each tool/machinery.
3. **Building on what others have said:** Individuals add to what others have said in a respectful manner. Learners should be encouraged to tolerate others' views
4. **Experiential learning:** Learners watch videos on health and safety protocols in the use of workshop tools/machinery and share their observations with the whole class.
5. **Problem-Based learning:** Learners are given opportunity to practically use workshop tools/ machinery to build a given prototype while observing health and safety protocols.

At the workshop, each learner should be guided to use various tools and machinery, in line with health and safety protocols. Other learners observe and comment on how equipment has been handled.

Key Assessment

Level 1 Recall

1. List the various types of accidents in a workshop
2. List the various types of accidents in a project site
3. Describe one major historical accident due to failure in following safety protocols.
4. Identify at least three (3) common injuries that could occur when using power tools. Explain how these injuries can be prevented through proper usage and safety measures.

Level 2 Skills of conceptual understanding:

1. Describe the primary health risks associated with using basic workshop tools and machinery. How can these risks be minimised or prevented?
2. Explain the importance of wearing personal protective equipment (PPE) while operating workshop tools. Provide specific examples of PPE for different tools.
3. Explain the procedure for inspecting and maintaining workshop tools to ensure they are in safe working condition. Why is regular maintenance crucial?
4. Describe the appropriate handling and storage practices for hazardous materials commonly used in workshops, such as paints, solvents, and adhesives.
5. Identify and explain the safety features and mechanisms found in basic workshop tools and machinery that are designed to protect users from potential accidents.
6. Explain any four (4) safety protocols you will consider:

a. at the workshop

b. when working with tools/machinery

7. Explain the importance of maintaining a well-organised workshop.
8. Describe the importance of using hand and power tools safely. Provide specific examples of potential hazards that might arise if safety protocols are not followed.
9. Compare and contrast the key safety considerations when using hand tools versus power tools. Give examples of situations where one type of tool might be more appropriate than the other.
10. Explain the steps you would take to prepare for using a specific hand tool. Include details about selecting the correct tool for the task and the safety precautions you would take.

Level 3 Strategic Thinking

1. Choose a power tool and outline the safety guidelines that must be followed when operating it. Highlight any specific protective equipment that should be worn.

2. Demonstrate the correct way to hold and manipulate a common hand tool, such as a hammer or screwdriver, to minimise the risk of injury. Use both written instructions and illustrations.
3. Design a safety protocol for a given workspace, example: workshop, laboratory, etc.
4. Design a sample safety manual for a given tool or machine.

Section 2 Review

1. Can learners list and explain the accidents that occur in engineering practice?
2. Would learners be able to identify and explain the causes of accidents in engineering practice and its effects?
3. Are learners familiar with the health and safety protocols associated with basic workshop tools?
4. Can learners use both hand and power tools according to proper safety protocols.
5. Can learners conduct a risk assessment of a given project?

Further Reading

- Kemper, J.D. and Sanders B.R., (2001), "*Engineers and Their Profession*", Oxford University Press.

Teaching/Learning Resources

1. Projector
2. Laptop
3. Videos and pictures on accidents in engineering practice
4. Videos on health and safety in the use of workshop tools/machinery
5. Various workshop tools and machinery

References

- Hughes, P. & Ferrett, E. (2012). *Introduction to Health and Safety in Construction: The Handbook for the Construction Professional and Client.*

SECTION 3: PROFESSIONAL ETHICS

Strand: **Engineering Practice**

Sub-strand: Ethics and Professional Practice

Learning Outcome: *Explain the importance of ethical behaviour in engineering practice*

Content Standard: Demonstrate knowledge and appreciation of ethics in engineering practice

INTRODUCTION AND SECTION SUMMARY

Ethics in engineering refers to the moral principles and standards that guide professionals in making decisions and carrying out their work responsibly, considering the impact on individuals, communities and the environment. Ethical behaviour in engineering is characterised by the adherence to a code of conduct that upholds fundamental values such as honesty, integrity, accountability, and respect for human rights. It ensures that engineering practices prioritise safety, sustainability and the greater welfare of humanity. Conversely, unethical behaviour in engineering encompasses actions that breach professional standards and occurs when professionals deviate from these moral principles and use their knowledge or skills to pursue self-interest, engage in fraudulent activities, compromise safety standards, or ignore the potential negative consequences of their work. Unethical practices in engineering can lead to disastrous outcomes, endangering lives, damaging the environment and eroding public trust in the profession. This section explores the relevance of ethics in engineering practice by delving into several key aspects of ethics. It examines how ethical considerations play a pivotal role in ensuring safety and reliability in engineering projects, maintaining public trust, fostering sustainable development, and addressing social and cultural implications.

The weeks covered by the section are:

Week 5: Ethics and Professional Practice

Week 6: Ethical Behaviour in Daily Life and Engineering Practice

SUMMARY OF PEDAGOGICAL EXEMPLARS

In this section consider using managing talk-for-learning and experiential learning to achieve the content standard. Moderate discussions so that learners explain their understanding of ethical and unethical behaviours in everyday life. Let learners watch videos on ethical and unethical behaviours in everyday life. Learners further share their experiences of such behaviours. Consider summarising learners' thoughts using concept maps or webbing. Learners' can build on what others say and catalogue ethical and unethical behaviours in engineering practice

ASSESSMENT SUMMARY:

Oral responses can be elicited in class discussions following a video show on ethical and unethical behaviours in everyday life. Learners can also be encouraged to outline challenges engineers face in their professional lives which often involve balancing competing interests, technical constraints, and ethical considerations and present a written, oral or power point presentation in class. Provide the learners with a selected case study or scenarios and allow them some time to read and analyse each situation. Let learners identify the ethical issues and potential dilemmas present in each scenario. These should contribute to learners' formative assessment.

Week 5

Learning Indicator(s):

1. *Capable of explaining ethical and unethical behaviours*
2. *Capable of explaining the relevance of ethics in engineering practice*

Theme or Focal Area 1:

Ethics in engineering refers to the moral principles and standards that guide professionals in making decisions and carrying out their work responsibly, considering the impact on individuals, communities, and the environment. Ethical behaviour in engineering upholds fundamental values such as honesty, integrity, accountability, and respect for human rights. It ensures that engineering practices prioritise safety, sustainability, and the greater welfare of humanity.

Conversely, unethical behaviour in engineering occurs when professionals deviate from these moral principles and use their knowledge or skills to pursue self-interest, engage in fraudulent activities, compromise safety standards, or ignore the potential negative consequences of their work. Unethical practices in engineering can lead to disastrous outcomes, endangering lives, damaging the environment, and eroding public trust in the profession.

Ethical Behaviours:

1. **Integrity:** Engineers should uphold honesty and integrity in their work, being truthful about their findings and not manipulating data to achieve desired results.
2. **Safety:** prioritise safety in all engineering projects, considering the well-being of individuals and the environment. Ensure that designs and constructions adhere to safety standards.
3. **Respect for Diversity:** Embrace diversity and treat all colleagues, clients, and community members with respect, irrespective of their background or beliefs.
4. **Environmental Responsibility:** Design and implement engineering solutions that are environmentally sustainable and minimise negative impacts on ecosystems and natural resources.
5. **Quality Workmanship:** Strive for excellence in engineering work, ensuring that designs and constructions are of high quality and meet industry standards.
6. **Innovation and Creativity:** Encourage innovation and creative problem-solving to come up with efficient and effective engineering solutions.
7. **Transparency:** Be transparent in communicating project progress, potential risks, and challenges to stakeholders, including clients and the public.
8. **Teamwork:** Collaborate effectively with colleagues, valuing their input and expertise in engineering projects.
9. **Professionalism:** Conduct yourself in a professional manner, adhering to ethical guidelines and maintaining a positive reputation within the engineering community.
10. **Whistleblowing:** Involves reporting any unethical or illegal activities within an organisation or industry to the appropriate authorities or stakeholders.

Unethical Behaviours:

1. **Plagiarism:** Copying or presenting someone else's work or ideas as one's own without proper attribution is unethical and a violation of intellectual property rights.

2. **Bribery and Corruption:** Engaging in bribery or corruption to gain favours, contracts, or advantages in engineering projects undermines fairness and transparency.
3. **Cutting Corners:** Sacrificing safety, quality, or compliance with regulations to save time or money is unethical and can lead to dangerous consequences.
4. **Discrimination:** Discriminating against individuals based on their gender, race, religion, or any other factor is unethical and goes against the principles of equality and diversity.
5. **Environmental Negligence:** Ignoring environmental impacts or neglecting environmental regulations in engineering projects is unethical and harmful to the planet.
6. **Conflicts of Interest:** Failing to disclose conflicts of interest that could compromise objectivity and impartiality in decision-making is unethical.
7. **Misrepresentation:** Providing false information or data in engineering reports or presentations is unethical and can lead to misinformed decisions.
8. **Inadequate Testing:** Failing to conduct thorough testing and safety checks on engineering projects can lead to avoidable accidents and harm to people and the environment.
9. **Infringing on Intellectual Property:** Using patented technology or copyrighted materials without proper authorisation is unethical and can lead to legal consequences.

Learning Tasks

1. Provide examples of ethical behaviours engineers should follow.
2. Give examples of unethical behaviours that engineers should avoid.
3. Describe the importance of ethical conduct in engineering projects.
4. Compare and contrast ethical and unethical behaviours in engineering, highlighting the impact on the profession and society.
5. Discuss selected ethical behaviours and professional code of conduct as outlined in the Ghana Institution of Engineering Code of Ethics and Professional Conduct handbook.

Theme or Focal Aaea 2:

This learning indicator explores the relevance of ethics in engineering practice by delving into several key aspects. It examines how ethical considerations play a pivotal role in ensuring safety and reliability in engineering projects, maintaining public trust, fostering sustainable development, and addressing social and cultural implications.

Some key reasons why ethics is relevant in engineering practice:

1. **Safety and Welfare of Society:** Engineers have a duty to prioritise the safety and welfare of the public. Whether designing bridges, buildings, medical devices, or software, the choices made by engineers can have significant consequences on people's lives. Ethical considerations help ensure that engineering solutions are designed to minimise risks and protect human well-being.
2. **Environmental Sustainability:** In an era of increasing environmental concerns, engineers are tasked with developing solutions that are environmentally sustainable. Ethical practices prompt engineers to consider the long-term impact of their designs on the environment, including resource depletion, pollution, and climate change.

3. **Equity and Social Justice:** Engineering decisions can have social and economic implications. Ethical engineering practices consider the equitable distribution of resources, accessibility, and inclusivity, aiming to reduce disparities and promote social justice.
4. **Informed Consent:** In certain engineering projects, such as medical devices or data collection systems, obtaining informed consent is essential. Ethical considerations involve ensuring that individuals are adequately informed about potential risks and benefits, and their consent is obtained without coercion or deception.
5. **Transparency and Accountability:** Ethical engineering practices promote transparency in decision-making processes. Engineers should be accountable for their actions, and ethical guidelines help foster a culture of responsibility and accountability.
6. **Avoiding Conflicts of Interest:** Ethical engineering demands that professionals act with integrity and avoid conflicts of interest that could compromise the quality and safety of their work. This includes not prioritising personal gains over the well-being of the public.
7. **Continuing Education and Professional Development:** Ethical engineering involves a commitment to continuous learning and staying up to date with the latest technological advancements, safety standards, and ethical considerations. This ensures that engineers maintain the highest level of competence in their field.
8. **International Collaboration:** In today's interconnected world, engineers often work across borders and cultures. Ethical guidelines provide a common framework for professionals to adhere to regardless of their geographical location, promoting consistency and accountability.
9. **Public Trust and Reputation:** Maintaining public trust is essential for the engineering profession's reputation. Ethical behaviour builds confidence in the industry, encouraging the public to embrace technological advancements and innovations.
10. **Adherence to Codes of Ethics:** Many engineering organisations have established codes of ethics and/or codes of conduct that their members are expected to follow. Adhering to these codes helps ensure that engineering professionals uphold the highest ethical standards in their practice.

The process of ethical decision-making:

The process of ethical decision-making in engineering can be summarised in the following steps:

1. ***Identify the Ethical Issue:*** Clearly define the ethical dilemma or issue at hand. Recognise the potential conflicts between different values, interests, or stakeholders that might arise from the engineering decision.
2. ***Gather Relevant Information:*** Collect all pertinent facts, data, and information related to the ethical issue. Consider the engineering, social, environmental, and economic aspects that may be affected by the decision.
3. ***Understand Ethical Principles and Codes:*** Familiarise yourself with the relevant ethical principles, codes of conduct, and guidelines for engineers established by professional bodies, such as the National Society of Professional Engineers (NSPE) in the United States and the Ghana Institution of Engineering.
4. ***Identify Stakeholders:*** Recognise the individuals, groups, or communities who will be affected by the engineering decision. Consider their rights, interests, and perspectives in the decision-making process.
5. ***Analyse Alternatives:*** Explore various alternative solutions to the ethical dilemma. Consider the potential consequences and impacts of each option, including short-term and long-term effects on stakeholders and the environment.

6. ***Apply Ethical Theories:*** Utilise ethical theories, such as utilitarianism, deontology, virtue ethics, or others, to assess the proposed alternatives. These theories provide frameworks for evaluating actions based on their consequences, moral rules, or character-based considerations.
7. ***Seek Input and Collaboration:*** Engage in discussions with colleagues, experts, and affected stakeholders to gain diverse perspectives and insights on the ethical issue.
8. ***Make the Decision:*** Based on the analysis and ethical principles, choose the course of action that is most aligned with ethical standards, professional codes, and the well-being of stakeholders.
9. ***Implement and Monitor:*** Put the decision into action while considering any possible unintended consequences. Continuously monitor the effects and adjust if necessary to ensure ethical objectives are met.
10. ***Reflect and Learn:*** After implementing the decision, reflect on the outcome and the ethical decision-making process. Identify areas for improvement and apply the lessons learned to future ethical challenges.

Learning Task

1. Identify ethical and unethical behaviours faced by engineers in decision making involving small projects within the community.
2. Discuss consideration that determine whether an engineer’s behaviour can be classified as ethical or unethical.
3. Assess the significance of incorporating ethical considerations into the design and development phase of an engineering project, and how it influences the project's success and long-term sustainability.
4. Discuss the impact of ethical and unethical behaviour of engineers on society.
5. Explore the ethical challenges related to emerging technologies, such as artificial intelligence and genetic engineering, and discuss the importance of establishing ethical frameworks to guide their responsible implementation.
6. Illustrate the relationship between ethical considerations and legal obligations in engineering practice, and how adherence to ethical principles can mitigate potential legal issues.
7. Explore the influence of cultural and societal norms on ethical decision-making in engineering projects and propose strategies to address potential conflicts that may arise.

Pedagogical Exemplars

Managing talk-for-learning:

1. In a moderated discussion, learners explain their understanding of ethical and unethical behaviours in everyday life. Learners further share their experiences of such behaviours. Building on what others have said: Facilitator adds to the explanations offered and experiences shared.
2. Collaborative learning: Learners sit in mixed gender and mixed ability groups, to list examples of ethical and unethical behaviours other than those previously discussed. Each group elects a representative to present their work.
3. In a moderated discussion, individual learners explain the relevance of ethics in engineering practice.
4. Learner's critique what others say and add on to it.

Experiential learning: Learners watch videos on ethical and unethical behaviours in everyday life.

Case Study: Learners are presented with case studies to examine and make ethical judgements about those cases.

Key Assessment

Level 1 Recall:

1. Explain what ethical behaviour means in the context of engineering practices.
2. Define unethical behaviour in the field of engineering.
3. Provide examples of ethical behaviours engineers should follow.
4. Give examples of unethical behaviours that engineers should avoid.
5. Describe the importance of ethical conduct in engineering projects.

Level 2 Skills of conceptual understanding:

1. Compare and contrast ethical and unethical behaviours in engineering, highlighting the impact on the profession and society.
2. Analyse a specific case where an engineering project involved ethical considerations and discuss the potential consequences of unethical behaviour.
3. Explain the role of professional codes of ethics in guiding engineers' conduct and decision-making.
4. Give examples of three ethical dilemmas engineers might face when balancing cost, safety, and environmental concerns in a project.

Level 3 Strategic Thinking

1. Propose strategies and mechanisms that can be implemented to encourage ethical behaviour in the engineering field.
2. Investigate historical incidents where unethical engineering practices led to significant societal or environmental consequences and discuss the lessons learned from these events.

Week 6

Learning Indicator(s):

1. *Distinguish between ethical and unethical behaviours in engineering practice*
2. *Demonstrate ethical behaviour in case study scenarios*

Theme or Focal Area 1:

Ethical behaviour in engineering is characterised by the adherence to a code of conduct that prioritises integrity, honesty, transparency, and respect for human rights and the environment. Engineers are expected to prioritise safety, sustainability, and social welfare in their decision-making processes.

On the other hand, unethical behaviour in engineering encompasses actions that breach professional standards, prioritise personal gain over the common good, or neglect the potential consequences of engineering projects.

Some key points to help SHS learners understand the difference between ethical and unethical behaviours in engineering practice:

1. Professional Responsibility:

Ethical Behaviour: Engineers have a responsibility to prioritise the safety and well-being of the public when designing and implementing engineering projects. They should follow established codes and standards to ensure their work meets the required safety and quality criteria.

Unethical Behaviour: Neglecting safety concerns, cutting corners, or compromising the quality of work to save time or money can lead to dangerous outcomes and is considered unethical.

2. Honesty and Integrity:

Ethical Behaviour: Engineers should be honest and transparent in their communication and work. They should not misrepresent data or information and should admit mistakes when they occur.

Unethical Behaviour: Falsifying data, plagiarising work, or taking credit for someone else's ideas are dishonest behaviours that are unethical.

3. Conflicts of Interest:

Ethical Behaviour: Engineers should avoid situations where their personal interests or biases might conflict with their professional judgment. They should make decisions based on objective criteria, considering the best interests of the public and the profession.

Unethical Behaviour: Engaging in activities that could compromise the objectivity of professional judgment, such as accepting bribes or participating in projects where there is a clear conflict of interest, is unethical.

4. Environmental and Social Impact:

Ethical Behaviour: Engineers should consider the environmental and social impact of their projects. They should strive to minimise negative consequences and promote sustainable practices.

Unethical Behaviour: Ignoring environmental regulations, contributing to pollution, or exploiting vulnerable communities for personal gain are examples of unethical behaviour.

5. Respect for Intellectual Property:

Ethical Behaviour: Engineers should respect intellectual property rights and give credit to the original authors or inventors when using their work.

Unethical Behaviour: Plagiarising, copying designs without permission, or using patented technology without proper authorisation are unethical actions.

6. Professional Competence:

Ethical Behaviour: Engineers should only take on projects that align with their area of expertise and competence. They should continuously update their skills and knowledge to ensure they can deliver high-quality work.

Unethical Behaviour: Taking on projects beyond one's capabilities, leading to substandard work or endangering public safety, is unethical.

Educating SHS learners about ethical engineering practices will help them become responsible and conscientious professionals who contribute positively to society while upholding the integrity of the engineering profession.

Learning Task

1. Discuss why ethical behaviour is vital in any profession, including engineering.
2. Compare and contrast ethical and unethical behaviours in engineering practice. Provide specific examples for each.
3. Brainstorm with learners on how an engineer can recognise ethical dilemmas in their work, and what steps they can take to address them.
4. Consider a situation where an engineer may face pressure to compromise their ethical principles. Brainstorm on how they could handle this situation ethically.
5. Explore how a code of ethics or a set of professional standards such as the GhIE Code of ethics and Professional conduct can guide engineers in making ethical decisions.
6. Discuss the impact of unethical engineering practices on society, the environment, and public trust in the profession.
7. Examine conflict of interest scenarios and how professionals can manage them.

Theme or Focal Area 2:

The challenges engineers face in their professional lives often involve balancing competing interests, technical constraints, and ethical considerations. Case studies help engineers explore how to navigate these complex dilemmas while upholding ethical standards. These scenarios might involve issues such as environmental impact, safety and risk assessment, conflicts of interest, data privacy, intellectual property, and social justice, among others.

Case Study 1: Environmental Impact Assessment

Scenario: You are working as a civil engineer on a project that involves constructing a large industrial facility near a sensitive ecological area. The project has the potential to cause significant environmental impacts, including habitat destruction and water pollution.

Ethical Behaviour:

1. ***Conducting a Comprehensive Environmental Impact Assessment (EIA):*** As an ethical engineer, you should perform a thorough EIA to identify all potential environmental impacts of the project. This assessment should include input from environmental experts, stakeholders, and affected communities.

2. ***Transparency and Stakeholder Engagement:*** Engage with all relevant stakeholders, including local communities, environmental organisations, and regulatory authorities, throughout the planning and development process. Be transparent about the project's potential impacts and actively seek feedback and concerns from stakeholders.
3. ***Mitigation Measures:*** Work to implement robust mitigation measures to minimise the environmental impacts of the project. This might involve redesigning certain aspects of the facility, incorporating eco-friendly technologies, or adopting best practices to reduce pollution.
4. ***Compliance with Regulations:*** Ensure that the project adheres to all environmental regulations and standards set by local and national authorities. This includes obtaining the necessary permits and licenses.
5. ***Continuous Monitoring:*** After the project is operational, implement a comprehensive monitoring plan to assess its actual environmental impact. If any adverse impacts are identified, take prompt action to rectify the situation and prevent further harm.

Case Study 2: Safety Concerns in Structural Design

Scenario: You are a structural engineer working on a bridge construction project. During the design phase, you discover that using certain cost-cutting measures might compromise the bridge's safety and longevity.

Ethical Behaviour:

1. ***Prioritising Safety:*** As an ethical engineer, safety should always be your top priority. Refrain from compromising on structural integrity or materials quality to save costs.
2. ***Professional Integrity:*** Maintain professional integrity by adhering to engineering principles, codes, and standards when designing the bridge. Avoid succumbing to pressure from stakeholders to overlook safety concerns for financial gains.
3. ***Collaboration and Consultation:*** Consult with other experienced engineers, peers, or mentors to gain insights into alternative design options that maintain safety while keeping costs under control.
4. ***Transparency with Clients:*** Communicate openly and honestly with your clients about the potential risks associated with cost-cutting measures. Explain the importance of prioritising safety and the long-term consequences of compromising on it.
5. ***Reporting Unsafe Practices:*** If your concerns are not adequately addressed or if you encounter pressure to implement unsafe design practices, be prepared to report the issue to the appropriate authorities or seek advice from professional engineering organisations.

Case Study 3: Conflicts of Interest

Scenario: You are an electrical engineer working for a company that manufactures electrical components. You discover that some of the products being produced do not meet the required safety standards.

Ethical Behaviour:

1. ***Reporting Concerns Internally:*** Report the identified safety issues to your immediate supervisor and management within the company. Emphasise the importance of addressing these issues promptly to protect consumers and uphold the company's reputation.
2. ***Protecting Public Safety:*** If the company fails to take appropriate action, consider disclosing the safety concerns to the relevant regulatory authorities or consumer protection agencies to protect the public from potential harm.

3. ***Whistle-blower Protection:*** If you decide to report the issue externally, ensure that you are aware of the whistle-blower protection laws in your jurisdiction. This will help safeguard you from retaliation and unfair treatment for speaking out about the safety issues.
4. ***Refraining from Concealing Information:*** As an ethical engineer, avoid participating in any efforts to hide or downplay safety issues. Concealing such information could lead to serious consequences and undermine public trust in engineering professionals.
5. ***Ethical Decision Making:*** Make decisions that prioritise public safety and adhere to professional and ethical standards, even if they conflict with the company's financial interests. Remember that engineering professionals have a responsibility for public welfare.

Demonstrating ethical behaviour is of utmost importance in engineering practice. Below are some real-life examples of ethical behaviour in case study scenarios:

Case Study 4: Whistleblowing on Safety Concerns:

Scenario: An engineer working on a construction project observes that the contractor is using substandard materials that compromise the safety of the building.

Ethical Action: The engineer reports the issue to the project manager and higher authorities, even if it means potential conflicts or repercussions. By doing so, they prioritise the safety of the public and fulfil their duty as a responsible engineer.

Case Study 5: Informed Consent in Medical Device Development:

Scenario: Engineers are involved in developing a medical device that will be implanted in patients to assist with a specific medical condition.

Ethical Action: The engineers ensure that proper informed consent is obtained from patients participating in clinical trials or using the medical device. They prioritise patient safety, disclose potential risks, and give individuals the option to participate voluntarily while maintaining their privacy and dignity.

Case Study 6: Inclusive Design for Accessibility:

Scenario: Engineers are involved in designing public spaces, including buildings and transportation systems.

Ethical Action: The engineers prioritise inclusive design, ensuring that the spaces are accessible to individuals with disabilities or mobility challenges. They adhere to relevant accessibility standards and guidelines to create an inclusive environment for everyone, regardless of their abilities.

Case Study 7: Respect for Intellectual Property Rights:

Scenario: Engineers are collaborating with external partners on a research project and have access to proprietary information.

Ethical Action: The engineers respect intellectual property rights and ensure that confidential information is handled carefully. They do not disclose or misuse any proprietary information without proper authorisation, maintaining the trust of their partners and upholding ethical standards.

Case Study 8: Responsible Data Management in Artificial Intelligence (AI) Applications:

Scenario: Engineers are developing AI systems that process and analyse large amounts of user data.

Ethical Action: The engineers prioritise data privacy and security, ensuring that user data is anonymised, encrypted, and used only for legitimate purposes. They adhere to data protection regulations and inform users about how their data will be used to obtain informed consent.

Learning Tasks

1. **Case Study:** You are a junior engineer working on a construction project, and you notice that some substandard materials are being used by your colleagues. Guide learners to demonstrate ethical behaviour in this situation. Ask learners to discuss the steps they would take to address the issue while ensuring the safety and quality of the project.
2. **Case Study:** You discover that a senior engineer on your team is accepting bribes from a contractor to overlook safety violations during a project. Guide learners to discuss how they would handle this ethical dilemma. Ask them to indicate what actions they would take to maintain professional integrity and uphold ethical standards in the engineering practice.
3. **Case Study**: During an environmental impact assessment for a proposed engineering project, you find that the project might have significant negative effects on the local ecosystem. However, the project has the potential to bring significant economic benefits to the community. Guide learners to discuss how they would demonstrate ethical behaviour in this scenario. Ask them what factors they would consider in making a responsible decision as an engineer.

Pedagogical Exemplars

Managing talk-for-learning: In a moderated discussion, learners outline what they consider to be ethical and unethical behaviours in relation to responsibilities in engineering practice. Summarise learners' thoughts using concept maps or webbing.

Learners building on what others say and catalogue responsible and ethical behaviours on one hand and irresponsible unethical behaviours in engineering practice on the other hand.

Experiential learning: Learners watch videos on ethical and unethical behaviours in engineering practice and share observations, relative to the responsibilities of individuals in the case study, with the whole class.

Problem-Based Learning:

1. Present various case study scenarios reflecting conducts by engineers for learners to discuss, whether each conduct is responsible and ethical or irresponsible and unethical
2. Facilitator presents various scenarios for learners to indicate their course of action, while others critique or endorse the intended actions.
3. Learners come up with various scenarios for colleagues to express their possible actions for discussion. Encourage learners to accept and present views in a tolerant and respectful manner.

Key Assessment

Level 1 Recall:

1. What does "ethical behaviour" mean in the context of engineering practice?
2. Name one example of an ethical behaviour an engineer should exhibit in their profession.
3. Why is it important for engineers to adhere to ethical standards in their work?
4. Give a simple explanation of why ethical behaviour is vital in any profession, including engineering?
5. Identify and state one action that an engineer could take that would represent ethical behaviour and one action that would represent unethical behaviour in the following scenario:

A construction company plans to build a large housing complex in an ecologically sensitive area, home to endangered species and unique flora. The project promises economic growth and job opportunities for the local community, but it also poses a significant threat to the environment.

Level 2 Skills of conceptual understanding:

1. Compare and contrast ethical and unethical behaviours in engineering practice. Provide specific examples for each.
2. Discuss the potential consequences of an engineer engaging in unethical behaviour in their professional life.
3. Explain the concept of conflict of interest and its implications in engineering.
4. Provide examples of situations where conflicts of interest may arise and discuss the potential consequences of compromised decision-making.

Level 3 Strategic Thinking:

1. Analyse a historical case where an engineering project faced ethical challenges and discuss the outcomes of the situation.
2. Evaluate the role of engineering organisations in promoting ethical behaviour within the profession. How can they enforce ethical standards effectively?
3. Critically assess the impact of unethical engineering practices on society, the environment, and public trust in the profession.
4. Design a hypothetical scenario where an engineer faces conflicting ethical responsibilities and evaluate the possible courses of action they could take.
5. Develop a plan to raise awareness and promote ethical behaviour among engineering learners and professionals in your community or school.

Provide the learners with the selected case study scenarios below and allow them some time to read and analyse each situation. Let learners identify the ethical issues and potential dilemmas present in each scenario.

An example of “ethical issues and potential dilemmas present” in the scenarios:

The Safety Compromise:

A civil engineering firm is working on a large infrastructure project, and they have tight deadlines to meet. During the construction phase, some of the team members notice potential safety issues that could lead to accidents if not addressed. However, addressing these issues would cause delays and additional costs, putting pressure on the project timeline and budget. The team faces an ethical dilemma between prioritising safety and meeting project deadlines. What should they do, and how can they handle the situation ethically?

Case Study A: You are part of a team designing a new product, and your company wants to rush the production process to meet a tight deadline. However, doing so may compromise the product's safety and quality. How would you ensure ethical behaviour in this situation? How would you communicate your concerns to your team and superiors?

Case Study B: You have come across a design flaw in a critical component of a machine that your company manufactures. The flaw could lead to potential accidents and injuries if not addressed. What steps would you take to demonstrate ethical behaviour in handling this situation? How would you balance the urgency of the matter with ensuring proper testing and rectification of the flaw?

Case Study C: You are a consulting engineer working for a company, and you find out that the company has been manipulating test results to present false performance data of their products to potential clients. How would you handle this unethical practice? What actions would you take to prevent such behaviour from continuing and maintaining your professional credibility?

Case Study D: As an engineer, you are working on a project in a foreign country with different cultural norms and standards. You realise that some of the engineering practices followed by the local contractors may not align with international ethical standards. How would you navigate this situation to demonstrate ethical behaviour while respecting the local customs and practices?

Section 3: Review

1. Will learners be able to differentiate between ethical and unethical behaviours in engineering practice?
2. Can learners demonstrate ethical and unethical behaviours in case study scenarios?
3. Can learners determine the right cause of action in an ethical dilemma?

Further Reading

GhIE Code of Ethics and Professional Conduct

Ethical Principles Video Series: This resource explores each ethical principle, giving students an understanding of what the principle means, its supporting traits, how it plays out in real-world examples, and how students can use it in their own lives.

Teaching/Learning Resources

1. Projector
2. Laptop
3. Videos on ethical and unethical behaviours in everyday life
4. Videos on ethical and unethical behaviours in engineering practice

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SECTION 4: ELECTRICAL AND ELECTRONIC CIRCUITS

Strand: **Energy Systems**

Sub-strand: Circuits and Machines

Learning Outcome: *Characterise the elements of DC circuits*

Content Standard: Demonstrate an understanding of the analysis of simple electric circuits from first principles and through simulation tools

INTRODUCTION AND SECTION SUMMARY

This section focuses on the fundamentals of Direct Current (DC) electrical and electronic circuits. Understanding these basic elements is essential as they form the building blocks of modern electrical and electronic systems and devices that power our everyday lives. Circuit diagrams are graphical representations of electrical and electronic circuits, used to convey the connections and functionality of various components within a circuit. These symbols are standardised and universally recognised, making it easier for engineers, technicians, and electricians to communicate and understand complex circuit designs. In electrical circuits, passive and active elements are fundamental components that play essential roles in controlling and regulating the flow of electric current. Analysing circuits using Kirchhoff's laws is an essential skill for anyone studying electrical engineering or related fields. In the field of electronics, circuit simulation software enables the understanding, designing, and testing of electrical circuits without the need for physical components. These tools allow users to create and simulate circuits virtually, making them essential learning aids. Four common user-friendly circuit simulation software tools are Proteus, LTspice, and CircuitLab. The electrical and electronic circuit can also be built and instruments such as voltmeter, ammeter and power meter can be used to measure the circuit terminal quantities.

The weeks covered by the section are:

Week 7: Behaviour and Characteristics of DC circuits Elements

Week 8: Basic Circuit Theorem

Week 9: Building and Simulating Circuits

SUMMARY OF PEDAGOGICAL EXEMPLARS

Consider managing talk-for-learning, initiating talk-for-learning and experiential learning. This will allow learners to share their experiences and appreciation of the components and their application in electric and electronic circuits as they have observed, simulated or built. Learners can watch videos of the elements of DC circuits, and they can also inspect circuit elements at the laboratory and share their observations. Learners can be put into small mixed ability groups to classify the circuit elements as passive and active and share their report with the whole class. Allow learners to critique their contribution and add to summarise. Consider a problem-based learning in which learners will be presented with various DC circuit problems to solve by calculation. They can subsequently set up the circuit problems in a simulator and simulate and then finally build the circuit on breadboard and measure voltages, current and power for the class to collectively discuss the results.

ASSESSMENT SUMMARY:

Consider a variety of assessment modes to satisfy all categories of learners and to give learners the opportunity to express their understanding of the major themes in the section. Provide samples of DC elements and have learners identify them. Allow learners to describe the purpose of these circuit elements. Learners can also be encouraged to outline the key characteristics of active and passive elements and give examples of commonly used active elements and present a written, oral or power point presentation in class; which can contribute to learners' summative assessment. Ask learners to compare passive and active elements in given circuits. Provide learners with a hypothetical circuit and ask them to predict how the violation of KCL or KVL would affect the circuit's behaviour. Present learners with scenarios involving DC circuits where they need to calculate voltages, currents and power. Ask them to demonstrate the application of the power formula and consider different circuit configurations. Present learners with circuit problems, in a problem-based learning, which learners will solve by calculation, simulation and practically by building and measuring the circuit terminal quantities such as voltages, currents and power.

Week 7

Learning Indicator(s):

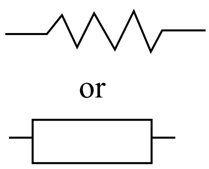
1. *Identify the basic elements of DC electric and electronic circuits and sketch their circuit symbols.*
2. *Classify circuit elements into passive and active elements*

Theme or Focal Area 1:

This focal area is on the fundamental components of Direct Current (DC) electric and electronic circuits. Understanding these basic elements is essential as they form the building blocks of modern electrical and electronic systems and devices that power our everyday lives.

Circuit diagrams are graphical representations of electrical circuits, used to convey the connections and functionality of various components within a circuit. These symbols are standardised and universally recognised, making it easier for engineers, technicians, and electricians to communicate and understand complex circuit designs.

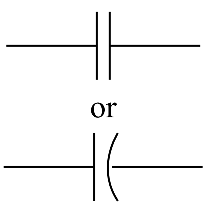
1. **Resistor:** A resistor is an electronic component designed to impede or restrict the flow of electric current in a circuit. Its primary function is to create a specific amount of resistance to control the flow of electrons. Resistors are commonly used to limit current, divide voltage, and protect sensitive components from excessive current flow. The resistance of a resistor is measured in ohms (Ω).



The Symbol of a Resistor

Figure 38: Resistors

2. **Capacitor:** Capacitors are passive components used to store and release electrical energy in the form of an electric field. They consist of two conductive plates separated by an insulating material (dielectric). When a voltage is applied across the plates, electrons accumulate on one plate, creating a negative charge, while an equal number of electrons leave the other plate, creating a positive charge. Capacitors are used for filtering, energy storage, coupling, and timing applications in electronic circuits. The capacitance of a capacitor is measured in Farad (F).



The Symbol of a capacitor

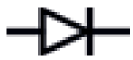
Figure 39: Capacitors

3. **Inductor:** Inductors are also passive components and are designed to store energy in the form of a magnetic field when an electric current flows through them. They consist of a coil of wire wound around a core material. When current changes, the magnetic field induces a voltage across the inductor, resisting changes in current. Inductors are commonly used in filters, transformers, and various energy storage applications. The inductance of an inductor is measured in Henry, (H).

The Symbol of an Inductor

Figure 40: A picture of Inductors

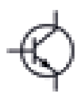
4. **Diode:** Diodes allow current to flow in one direction only and block it in the opposite direction. They are used for rectification, signal demodulation, and voltage regulation in both DC circuits.



The Symbol of an Diode

Figure 41: A picture of Diodes

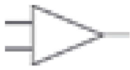
5. **Transistor:** Transistors are semiconductor devices that can amplify or switch electrical signals. They are fundamental components in electronic devices like computers, amplifiers, and other electronic circuits.



The Symbol of an Transistor

Figure 42: A picture of Transistor

6. **Integrated circuits (IC):** An integrated circuit (IC), also known as a microchip or chip, is a compact arrangement of electronic components such as transistors, capacitors, resistors, and diodes, fabricated on a single piece of semiconductor material, typically silicon. The components are interconnected in a way that allows them to perform specific functions, such as amplification, signal processing, logic operations, or memory storage.

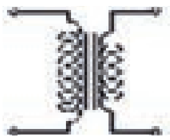


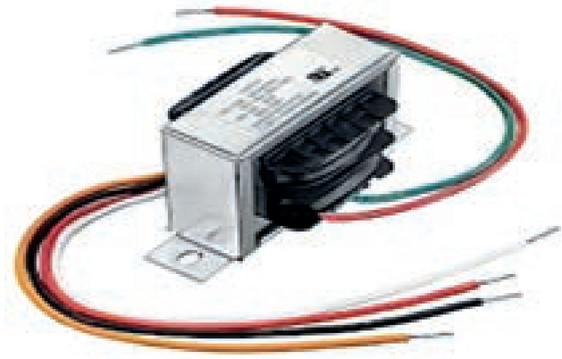
The Symbol of an Integrated Circuit

Figure 43: A picture of Integrated Circuit (IC)

Source: lens.google.com, url: https://shorturl.at/ijryC, [accessed: 22.03.2024]

7. **Transformer:** Transformer is a device used to transfer electrical energy between two or more circuits through electromagnetic induction. It is commonly used to step up or step-down voltage levels in power distribution systems.





The Symbol of a Transformer

Figure 44: A picture of a Transformer

8. **Switches (S):** Switches are fundamental components used to control the flow of current in a circuit. They can be either mechanical or electronic. When a switch is closed (turned ON), it allows current to flow through the circuit. When it is open (turned OFF), it interrupts the current path, preventing current flow. Switches play a crucial role in controlling the operation of electronic devices and systems.

The Symbol of a Switch

Figure 45: A picture of a Switch

Source: Lens.google.com, url: https://shorturl.at/pzZ47, [accessed: 22.03.2024]

Learning Task

1. Discuss with learners, two (2) categories of elements that are present in every DC circuit.
2. Discuss with learners, two (2) basic elements that are present in every AC circuit.
3. Guide learners to identify basic elements that are found in DC circuit (using available circuits in the lab) as well as their symbols.
4. Guide learners to represent components in a circuit using circuit diagrams.
5. Guide learners to characterise DC circuit components
6. Guide learners to sketch the electrical circuit symbols of the following devices: Battery, Fuse, Lamp, Antenna, Microphone, Speaker, LED, Bell, Generator, Fluorescent light, Meter, One-way one gang switch, Two-way one gang switch, Intermediate switch, Sockets, Earthing
7. Discuss the difference between active and passive elements.
8. Differentiate between active elements in electrical circuits and those of electronic circuits.

Theme or Focal Area 2:

In electrical and electronic circuits, passive and active elements are fundamental components that play essential roles in controlling and regulating the flow of electric current. Understanding the differences between these two types of elements is crucial for designing and analysing electrical circuits.

Passive elements are components that do not introduce energy (on their own) into the circuit and cannot amplify signals. They can only receive, store, or dissipate energy. Examples of passive elements include:

1. **Resistor:** A resistor is a component that opposes the flow of current. It dissipates energy in the form of heat.
2. **Capacitor:** A capacitor is a component that stores electrical energy in an electric field between its plates. It can release stored energy over time.
3. **Inductor:** An inductor is a component that stores electrical energy in a magnetic field created by the current flowing through its coils. It can release stored energy over time.

Active elements: The are two categories of active elements depending on whether they are components that can introduce energy into the circuit or can amplify or manipulate signals. In electrical circuits, active elements are the energy producing elements (power source). However, in electronic circuits, active elements are those that magnify or manipulate the characteristics of signals. They require an external power source to operate. Examples of active elements in electrical circuits include:

1. Batteries: They convert chemical energy to electrical energy, which is DC.
2. Generators: They convert thermal/mechanical energy to electrical energy, which is AC
3. Solar Cells: They convert solar energy (from the sun) to electrical energy, which is DC

Examples of active elements in electronic circuit include

1. **Transistor:** A semiconductor device that can amplify and switch electronic signals and power. There are two main types: bipolar junction transistors (BJTs) and field-effect transistors (FETs).
2. **Diode:** A diode is a semiconductor device that allows current to flow in only one direction. It can be used for rectification or signal conditioning.

Electronic circuits containing both passive and active elements are known as active circuits. Examples include:

1. **Operational Amplifier (Op-Amp):** An integrated circuit that amplifies the difference between two input voltages. It is often used for signal processing and amplification.
2. **Integrated Circuit (IC):** These are active components that contain a combination of transistors, resistors, capacitors, and other elements integrated onto a single chip. They can perform a wide range of functions, from simple amplification to complex digital signal processing.

Learning Task

1. Guide learners to differentiate between passive and active circuit elements based on their behaviour in a circuit.
2. Engage learners in a discussion on how passive elements affect the flow of current in a circuit?
3. Explore the concept of energy dissipation in passive circuit elements and how it influences their classification.
4. Explore the role of active elements in signal amplification and signal processing within a circuit.
5. Compare and contrast the impedance characteristics of passive and active elements and their impact on circuit design.

Pedagogical Exemplars

1. **Initiating talk-for-learning**: The facilitator explains the differences between electric and electronic circuits. He/she further explains the application of electric circuits, introduces the basic elements of DC and AC circuits (including their functions), and draws a distinction between DC and AC circuits.
2. **Managing talk-for-learning**: Learners share experiences of components and their application in electric circuits they have observed or built in the lab.
3. **Experiential learning**: Learners watch videos on the elements of DC circuits. They also inspect circuit elements at the laboratory and share their observations.
4. **Experiential Learning**: Learners guided to set up circuits in Proteus or LTSpice and simulate for the characteristics of circuit elements.

Key Assessment

Level 1 Recall:

1. Give a list of active and passive components and ask for their symbols
2. Multiple-Choice Questions: Create multiple-choice questions that require learners to identify basic components of DC circuits, such as resistors, capacitors, inductors, and power sources. Example: Which component stores electrical energy in an electric circuit?

   a) Resistor b) Capacitor c) Inductor d) Diode
3. True/False Questions: Use true/false questions to assess learners' understanding of basic statements related to DC circuits. Example: True or False: In a DC circuit, the current flows in one direction only.

4. In an AC electric circuit, what component is used to store electrical energy?
5. Define Direct Current (DC) in electrical circuits.
6. Name two basic elements that are present in every DC circuit.
7. Name two basic elements that are present in every AC circuit.

Level 2 Skills of conceptual understanding:

1. Compare and contrast the advantages of using DC circuits over AC circuits in specific applications.
2. Describe the purpose of a capacitor in an AC circuit and provide an example of its practical application.
3. Differentiate between the characteristics of active and passive elements
4. In a DC circuit, if a light bulb is connected in series with a resistor, and both are connected to a power source, what happens to the brightness of the light bulb if the resistance of the resistor is increased?

Level 3 Strategic thinking

1. Circuit Analysis Problems: Present learners with simple DC circuit diagrams and ask them to calculate quantities like voltage, current, or resistance at different points in the circuit.
2. Short Answer Questions: Use short answer questions that require learners to explain the functions of various components in a DC or AC circuit and how they affect the circuit's behaviour.
3. Give a simple circuit problem and require learners to set them up in a simulator and simulate so they can comment on the responses of the circuit.

Week 8

Learning Indicator(s):

1. *Explain Kirchhoff's laws*
2. *Use Kirchhoff's laws to find currents and voltages in DC circuits.*

Theme or Focal Area 3:

Gustav Robert Kirchhoff (1824-1887) was a renowned physicist and mathematician who made significant contributions to various fields of science. In electrical circuit theory, he is best known for formulating Kirchhoff's Laws, which he published in 1845 while he was a university student.

Kirchhoff's Current Law (KCL): *It states that at any instant, the algebraic sum of currents at any junction (or node) in a network is zero.*

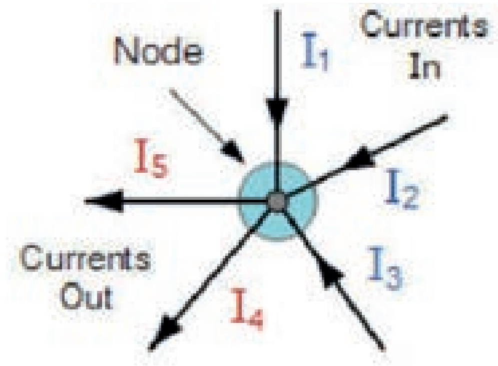


Figure 46: A picture illustrating KCL

Source: lens.google.com, url: https://shorturl.at/pDIX3, [accessed: 22.03.2024]

In simple terms, this means that the total current flowing into a junction is equal to the total current flowing out of the junction. This is because the charge is neither created nor destroyed at a junction; it can only flow in or out.

Kirchhoff's Voltage Law (KVL): *It states that at any instant in a loop, the algebraic sum of the EMFs acting around the loop is equal to the algebraic sum of the potential differences around the loop.*

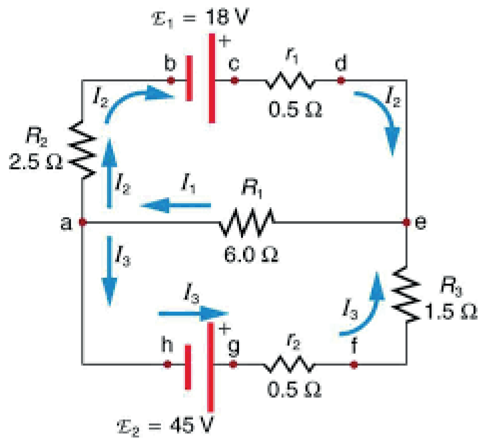


Figure 47: A picture illustrating KVL

Source: lens.google.com, url: https://shorturl.at/grvQR, [accessed: 22.03.2024]

I1 = I2 + I3 ……………………….KCL equation 1

E1 = I1R1 + I2 (r1 + R2)…………....KVL equation 2

E2 = I1R1 + I3 (r2 + R3)……………KVL equation 3

Series and Parallel Circuits

In series circuits, resistors are connected one after another, creating a single path for current flow. The equivalent resistance (R_T) of series resistors is the sum of individual resistances.

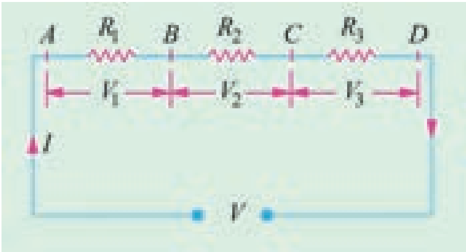


Figure 48: A picture of three resistors in Series

Source: lens.google.com, url: https://shorturl.at/ltOVW, [accessed: 22.03.2024]

Characteristics of a Series circuit

ii) The same current flows through all resistors

ii) Total potential difference is equal to the sum of individual potential differences

iii) Individual potential difference is directly proportional to individual resistance

iv) Total resistance is equal to the sum of individual resistances

v) Total power in a series circuit is equal to the sum of the individual values of power in the circuit.

Since the same current flows through each resistor, the supply voltage is equal to the sum of the potential differences across each resistor:

V = V1 + V2 + V3

V = IR, V1 = IR1, V2 = IR2, V3 = IR3

Total Resistance, RT = R1 + R2 + R3

Resistors connected in parallel

When resistors are connected in parallel in the same circuit, they can work as if each resistor were connected in a separate circuit.

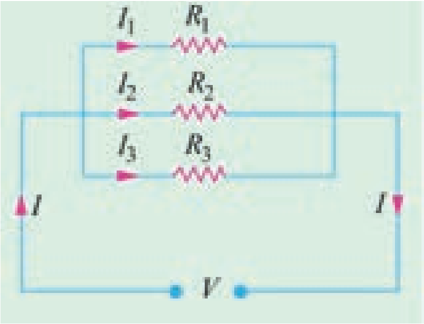


Figure 49: A picture of three resistors in Parallel

Source: lens.google.com, url: https://shorturl.at/amx59, [accessed: 22.03.2024]

Characteristics of a parallel circuit

- **i.** The same potential difference is across each resistor
- **ii.** Total current is equal to the sum of individual currents
- **iii.** Individual currents are inversely proportional to the individual resistances
- **iv.** Total power in a parallel circuit is equal to the sum of the individual values of power in each branch.

When three Resistors are connected in parallel,

$\mathbf{I = I_1 + I_2 + I_3}$

$I = \frac{V}{RT}$, $I_1 = \frac{V}{R1}$, $I_2 = \frac{V}{R2}$ and $I_3 = \frac{V}{R3}$

Where V is the applied voltage

R_T is the total resistance of the parallel combination

$$\frac{V}{RT} = \frac{V}{R1} + \frac{V}{R2} + \frac{V}{R3}$$

Dividing through by V

$$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

Hence

Total Resistance for the parallel combination, $\mathbf{R_T} = \frac{R1.R2.R3}{R1.R2 + R1.R3 + R2.R3}$

If two resistors are connected in parallel, what is the total resistance of the parallel combination?

$$\mathbf{R_T} = \frac{R1.R2}{R1 + R2}$$

Learning task

1. State Kirchhoff's laws
2. State three (3) characteristics each of series and parallel resistive circuits.

Theme or Focal Area 4:

Analysing DC circuits using Kirchhoff's laws is an essential skill for anyone studying electrical engineering or related fields. Kirchhoff's laws are two fundamental principles that govern the behaviour of electrical circuits. Sample problems solved using Kirchoff's Laws are presented below:

Question 1. Using figure 50 below,

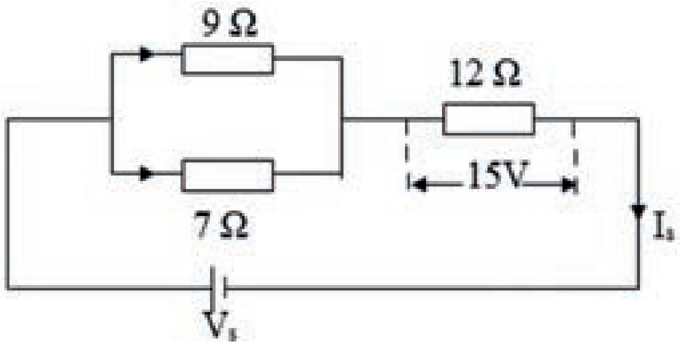


Figure 50

Calculate:

a) the total resistance R_T;

b) current, I_s;

c) voltage, V_s.

d) the voltage across the 9Ω resistor

Solution:

a) $R_p = \frac{9 \times 7}{9 + 7}$

$= \frac{63}{16}$

$= 3.9375\Omega$

$R_T = R_p + 12$

$= 3.9375 + 12$

$= 15.9375\Omega$

∴ The Total Resistance of the circuit, $R_T = 15.94\Omega$

b) $I_s = \frac{V}{R}$

Given V = 15V and R = 12Ω

$I_s = \frac{15}{12}$

$= 1.25A$

c) $V_s = V_p + 15V$

$V_p = I_s R_p$

$I_s = 1.25A$ and $R_p = 3.9375\Omega$

$V_p = 1.25 \times 3.9375$

$= 4.921875V$

$V_s = 4.921875 + 15$

$= 19.921875V$

d) Voltage across 9Ω Resistor, $V_p = 4.9218V$

Question 2. Using Kirchhoff's laws in figure 51,

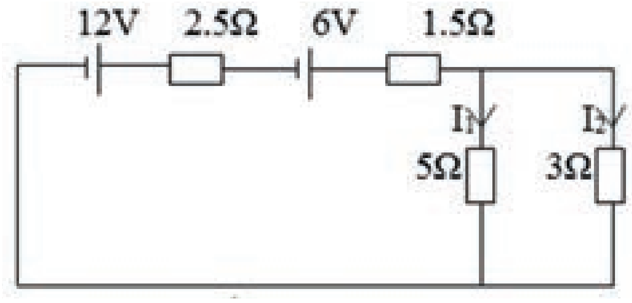


Figure 51

Calculate the current

i. I_1

ii. I_2

iii. the voltage across the 3Ω resistor

Solution

Resistors in Series, $R_s = 2.5\Omega + 1.5\Omega$

$= 4.0\Omega$

Total Voltage, Vs = 12V + 6V

= 18V

From the circuit diagram

$I_2 = I - I_1$ --------- Equation 1

$18 = 4I + 5I_1$ --------Equation 2

$18 = 4I + 3I_2$ -------Equation 3

Substituting equation 1 into equation 3

$18 = 4I + 3(I - I_1)$

$18 = 4I + 3I - 3I_1$

$18 = 7I - 3I_1$---------------Equation 4

Equation 2×3

$54 = 12I + 15I_1$-----------Equation 5

Equation 4 × 5

$90 = 35I - 15I_1$-----------Equation 6

Equation 5 + Equation 6

$144 = 47I$

$I = \frac{144}{47}$

$= 3.0638A$

i) Substituting I = 3.0638 into equation 2

$18 = 4I + 5I_1$

$18 = 4(3.0638) + 5I_1$

$18 = 12.2552 + 5I1$

$5I_1 = 18 – 12.2552$

$5I_1 = 5.7448$

$I_1 = \frac{5.7448}{5}$

∴ $I_1 = 1.14896A$

ii) Substituting I = 3.0638 into equation 3

$18 = 4I + 3I_2$

$18 = 4(3.0638) + 3I_2$

$18 = 12.2552 + 3I_2$

$3I_2 = 18 – 12.2552$

$3I_2 = 5.7448$

$I_2 = \frac{5.7448}{3}$

$I_2 = 1.9149A$

iii) The voltage across the 3Ω resistor, $V = 3I_2$

$= 3 \times 1.9149$

$= 5.7447V$

Question 3.

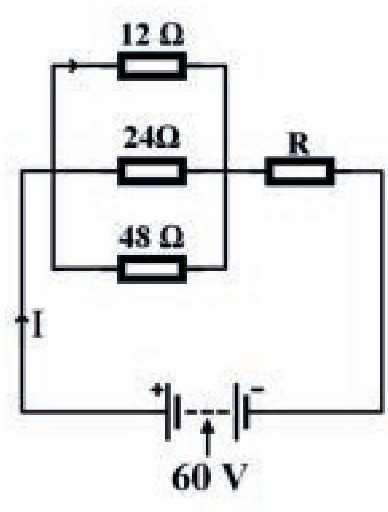


Figure 52

Figure 52 is a resistive network. If the power dissipated in the 12Ω resistor is 48W, calculate the

- **i.** current flowing in the 12Ω resistor
- **ii.** the total current (I) in the circuit
- **iii.** value of the resistor I

Answers

i. Current flowing in the 12Ω resistor, $I_1 = 2.0A$

ii. The total current $I = 3.5A$

iii. The value of Resistor $R = 10.2\Omega$

Question 4.

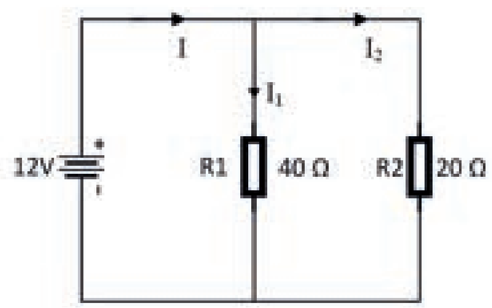


Figure 53

Figure 53 is a circuit diagram. Using the diagram, calculate the:

i) current (I_1) flowing through resistor R_1

ii) current (I) flowing through the circuit

ii) current (I_2) flowing through resistor R_2

Answers

i) The current, $I_1 = 0.3A$

ii) The Total current, $I = 0.9A$

iii) The current, $I_2 = 0.6A$

Question 5.

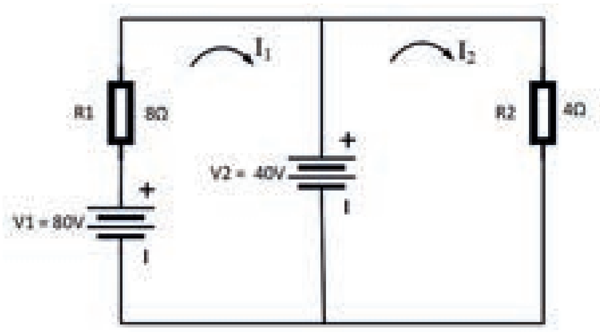


Figure 54

Using Kirchhoff's law in Figure 54, calculate

i. the value of current I_1

ii. the value of current I_2

Answers

i) Current $I_1 = 5A$

ii) Current I_2 = 10A

Learning task

1. Provide learners with a hypothetical DC circuit scenario and ask them to predict how changing one component would affect the circuit's behaviour using Kirchhoff's laws.
2. Apply Kirchhoff's laws to find currents and voltages in simple DC circuits.
3. Apply Kirchhoff's laws to find currents and voltages in moderately complex (up to 3 nodes or loops) DC circuits.
4. Apply Kirchhoff's laws to find currents and voltages in complex (multiple nodes or loops) DC circuits.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** Guide learners to search for the Kirchhoff law and share with the whole class.
2. **Question-and-answer sessions**, learners explain Kirchhoff's current and voltage laws. Critique their contribution and add to summarise.
3. **Problem-Based-Learning:** Set up Kirchoff's law problems and lead the class in discussion and solution to the problems.
4. **Collaborative learning:** Have learners working in mixed gender, mixed abilities to come up with circuit problems and apply Kirchoff's laws to solve them.
5. **Experiential Learning:** Set up circuits in simulators and determine the terminal quantities such as voltages, currents and power.

Key Assessment

Level 1 Recall

1. State Kirchoff's Laws
2. What is the total resistance value of two 10 Ohms resistors connected in parallel?
3. A 9V battery supplies two 5 Ω resistors connected in series. What is the value of current flowing through the circuit?

Level 2 Skills of conceptual understanding:

1. Describe Kirchhoff's first law and its significance in analysing electrical circuits.
2. Apply Kirchoff's Laws to solve moderately complex DC circuits involving not more than 3 junctions or loops.

Level 3 Strategic thinking

1. Apply Kirchoff's laws to solve complex problems on effective resistance for series and parallel resistances involving multiple loops and junctions.
2. calculate current and voltage using Kirchoff's laws for complex DC circuits involving multiple loops and junctions.

Week 9

Learning Indicator(s):

1. *Compute power in DC and single-phase AC circuits*
2. *Use a software tool to simulate simple circuits to derive current, voltage and power in DC circuits.*

Theme or Focal Area 1:

Power is the rate at which work is done or the rate of energy transfer. It measures how quickly energy is converted or used in a system. The SI unit of power is the watt, represented by the symbol "W."

Power (P) = Energy (E) / Time (t) or P = E / t
Where: P = Power in watts (W), E = Energy in joules (J) and t = Time in seconds (s)

Relationship between Power, Voltage, and Current:
P = VI for resistive circuits

Where: P = Power in watts (W), V = Voltage in volts (V) and I = Current in amperes (A)

Power in DC Circuits:
P = VI

$P = I^2R$

P =

Question 1. If you have a DC circuit with a voltage of 12V and a current of 2.0A, what is the power consumed by the circuit?

Question 2. In a series DC circuit, you have three resistors with values of 10Ω, 15Ω, and 20Ω, and a 24V battery. Calculate the total power dissipated in the circuit.

Question 3. In a parallel DC circuit, you have three resistors with values of 5Ω, 6Ω, and 8Ω, and a 12V battery. Calculate the total power dissipated in the circuit.

Question 4. In a DC circuit with a voltage of 120V and a current of 5A, what is the real power consumed?

Learning task

1. In a DC circuit, a 12 V battery is connected to a resistor with a resistance of 8Ω. Calculate the power dissipated in the resistor. Also, explain how the power value changes if the resistance is doubled while keeping the voltage constant.
2. A DC motor consumes 10 A of current from a 24 V battery while operating. The motor has an output shaft power of 180W. Calculate the efficiency of the motor. If the efficiency is found to be low, suggest some possible ways to improve it.
3. Solve for terminal quantities such as voltage and current in DC circuit and then compute the power.

Theme or Focal Area 2:

Circuit Simulation Software: In the field of electronics, circuit simulation software plays a crucial role in understanding, designing, and testing electrical circuits without the need for physical components. These tools allow users to create and simulate circuits virtually, making them an essential learning aid in education. Three commonly used user-friendly circuit simulation software tools are Proteus, LTspice and CircuitLab.

1. **Proteus:**Proteus is a popular circuit simulation tool that is widely used in education and hobbyist projects. It offers a simple and intuitive interface that makes it suitable for beginners. Proteus circuit builder allows students to drag and drop components onto the canvas, making it easy to assemble circuits.

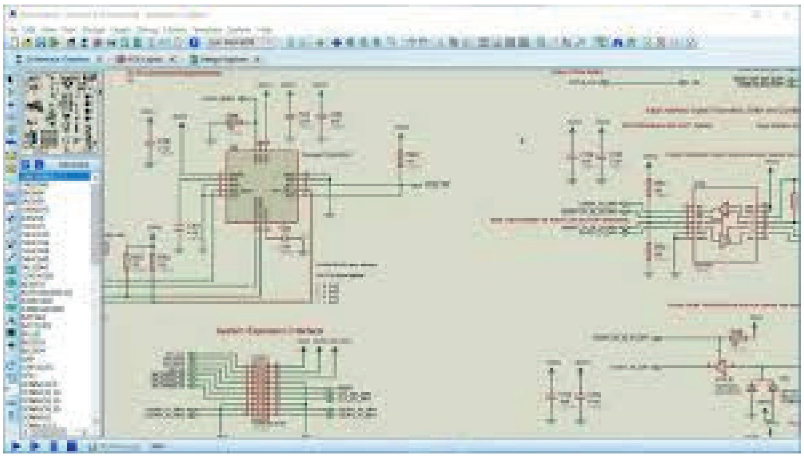


Figure 56: A picture of Proteus workplane

Source: Labcentre Electronics, url: https://images.app.goo.gl/M24yajruTLYgJuvH7, [accessed: 15.04.2024]

2. **LTspice:**LTspice is a powerful circuit simulation software widely used in engineering and educational settings. It offers more advanced features than Tinkercad but may have a steeper learning curve. It provides a **s**chematic editor where students can design circuits by placing components and connecting them with wires.

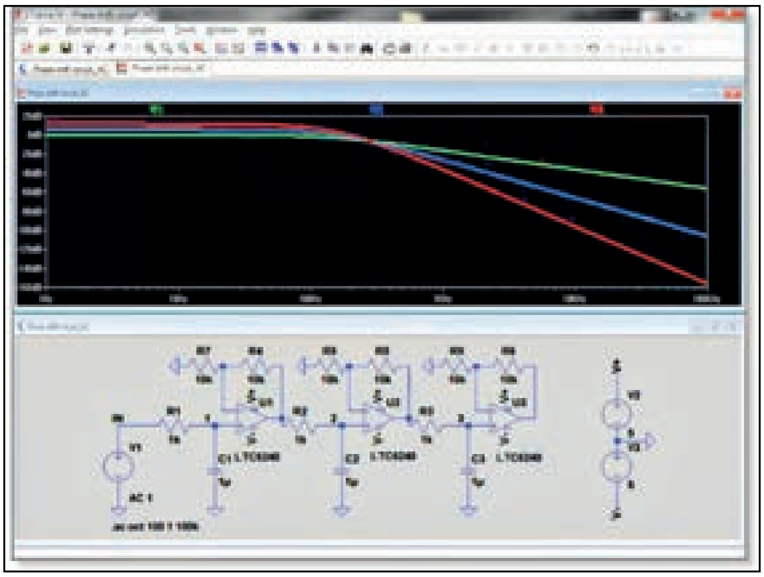


Figure 57: A picture of LTspice workplane

Source: LTSpice Info Centre, url: https://images.app.goo.gl/eodaM4uoggKNXcq26, [accessed: 15.04.2024]

3. **CircuitLab:**CircuitLab is another user-friendly online circuit simulator with a focus on simplicity and ease of use. It features a schematic editor that enables students to create circuits quickly and efficiently. It also includes a wide range of components and supports various simulation types.

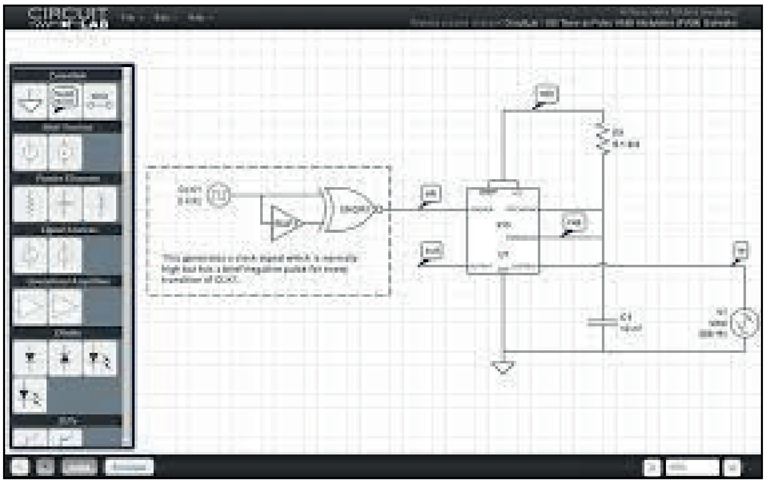


Figure 58: A picture of Circuitlab workplane.

Source: CircuitLab, url: https://images.app.goo.gl/mmZ1YVEApAncuo9F9, [accessed:15.04.2024]

Running Simulations:

After setting up the circuit parameters, it's time to run the simulation. Most software tools have a "simulate" or "run" button that initiates the analysis. The software will calculate the behaviour of the circuit based on the specified parameters and generate simulation results, such as voltage and current waveforms, which can be displayed on the screen.

Introduction to DC Circuits Simulation:

- Open the circuit simulation software (e.g., SPICE, LTspice, or any other tool you prefer) and create a new project.
- Design your DC circuit on the simulation interface by placing components like resistors, capacitors, and voltage/current sources.
- Once the circuit is ready, you can begin the simulation setup.

Setting Simulation Time and Analysing Transient or Steady-State Behaviour:

- Before running the simulation, determine the time span you want to observe. For transient analysis, set the simulation time long enough to capture the behaviour of interest. For steady-state analysis, you can set a shorter simulation time.
- Configure the simulation settings, selecting either transient or steady-state analysis.
- Run the simulation and observe the behaviour of the circuit over time (transient analysis) or once it reaches a stable state (steady-state analysis).

Measuring Current, Voltage, and Power:

- To measure current and voltage at specific locations in the circuit, place measurement probes accordingly. Probes are typically voltage probes (for voltage measurement) and current probes (for current measurement).
- After running the simulation, examine the waveforms displayed on the oscilloscope or plotter. You can use the cursors or markers to measure specific values.

- Analyse the measured values to understand how voltage and current change over time or at specific points in the circuit.

Analysing Power in DC Circuits:

- To calculate power dissipation in resistive elements (e.g., resistors), use the formula: Power (P) = Voltage (V). Current (I). This is valid for resistive elements in both DC circuits.
- Sum up the power dissipated across all resistors in the circuit and verify power conservation, which states that the total power supplied by voltage sources must equal the total power consumed by resistive elements.

Learning task

1. Guide learners to design a complex DC circuit with multiple components. Use the simulation software to find the total impedance (resistance), total current, and total power in the circuit. Provide step-by-step explanations for each calculation.
2. Confirm the answers in (1) using hand calculations.
3. Guide learners to build the same circuit using components from the lab on a breadboard and measure the current, voltage and power using instruments like ammeter and voltmeter.
4. Discuss the accuracy and limitations of the simulation software in replicating real-world circuit behaviour. Compare the software's predictions to actual measurements from a physical circuit and identify areas where the simulation may not accurately represent reality.
5. Guide learners to critique the effectiveness of the software tool in helping you understand the fundamental concepts of current, voltage, and power in DC circuits. Identify any areas where the software may have helped or hindered.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** The facilitator draws and explains the power relations of Apparent Power, Real Power and Reactive Power, including power factor. Facilitator further provides all relevant equations.
2. **Experiential learning**: Learners watch videos on setting up DC circuits in a simulator. They also try their hands on the simulator and share their experiences with their class.
3. **Problem-based learning**: Learners working in mixed ability and gender groupings, guided to solve for terminal quantities in given circuit problems through simulations.
4. **Experiential Learning**: Learners guided to design their own circuits in Proteus or LTSpice and simulate for the terminal quantities.

Key Assessment

Level 1 Recall

1. Define reactive power in a single-phase AC circuit.
2. How does reactive power differ from real power (active power)?
3. In a series DC circuit with resistances R1 and R2 connected in series across a voltage source V, how do you compute the total power dissipated in the circuit?
4. Provide the formula for the case in (2) and explain the steps to calculate it.

5. In a single-phase AC circuit with a purely resistive load R connected to an AC voltage source with voltage amplitude V and frequency *f*, what is the formula to calculate the average power dissipated in the resistor? Explain how to find the average power using the given formula.

Level 2 Skills of conceptual understanding:

1. Provide an example of a circuit where reactive power is present and explain its significance.
2. A DC circuit consists of three resistors R1, R2, and R3 connected in parallel across a voltage source V. Calculate the total power consumed by the resistors if their values are given as 10Ω, 20Ω, and 30Ω, respectively, and the voltage source is 12 V.
3. Present learners with scenarios involving DC and single-phase AC circuits where they need to calculate power in different components. Ask them to demonstrate their ability to apply the power formula and consider different circuit configurations.
4. Analyse the given single-phase AC circuit and compute the real power, reactive power, and apparent power.

Level 3 Strategic Thinking:

1. A DC circuit consists of three resistors R1, R2, and R3 connected in parallel across a voltage source V. Calculate the total power consumed by the resistors if their values are given as 10Ω, 20Ω, and 30Ω, respectively, and the voltage source is 12 V.
2. In a DC circuit with resistors and capacitors in parallel, calculate the total power dissipated in the circuit and explain the power distribution between the components.
3. Provide learners with a hypothetical scenario involving a faulty electrical device and ask them to calculate the power consumed and identify potential issues.
4. Have learners research and prepare a report on power quality issues in electrical systems and propose strategies for improving power efficiency.

Section 4: Review

1. Can learners identify the basic components used in DC circuits?
2. Are learners able to sketch the circuit symbols of DC and AC circuit components?
3. Would learners be able to classify circuit elements into passive and active elements?
4. Can learners state and explain Kirchhoff's laws?
5. Would learners be able to use Kirchhoff's laws to find currents and voltages in DC circuits?
6. Would learners be able to calculate power in DC and AC circuits?
7. Can learners use a software tool to simulate simple circuits to derive current, voltage and power in DC circuits?

Further Reading

- Hiley, J., Brown, K. E., & Hughes, E. (2001). Hughes Electrical & Electronic Technology-either edition.

Teaching/Learning Resources

1. Projector
2. Laptop

3. Videos on DC circuit elements
4. Assorted DC electric circuit elements (e.g., Inductors, capacitor, resistors, switches, etc.)
5. White board and marker
6. Simulation software (e.g., Proteus)

References

- Hiley, J., Brown, K. E., & Hughes, E. (2001). Hughes Electrical & Electronic Technology-either edition.

SECTION 5: RENEWABLE ENERGY SOURCES

Strand: **Energy Systems**

Sub-strand: Renewable Energy systems

Learning Outcome: *Explain the electricity production processes for the various renewable energy sources*

Content Standard: Demonstrate an understanding of the sources of renewable energy

INTRODUCTION AND SECTION SUMMARY

This section focuses on Renewable energy which refers to energy derived from naturally replenished sources, such as sunlight, wind, water, and geothermal heat. The importance of renewable energy lies in its ability to address environmental challenges, reduce greenhouse gas emissions, combat climate change, and promote energy security by diversifying our energy mix. Renewable energy refers to energy sources that are naturally replenished and are considered sustainable over the long term. Unlike fossil fuels such as coal, oil, and natural gas, which are finite and non-renewable, renewable energy sources can be harnessed without depleting their availability for future generations. Goals Related to Affordable and Clean Energy (SDG 7) aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Sustainable Cities and Communities (SDG 11) focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. It is crucial to compare various renewable energy sources concerning their availability, potential electricity generation, ease of energy production, cost of generation, technological maturity, and other relevant factors. This comparative analysis will help us better understand the strengths and limitations of different renewable energy options, aiding in informed decision-making for a sustainable energy future.

The weeks covered by the section are:

Week 10: Renewable Energy

Week 11: Energy Generation from Renewable Energy Sources

SUMMARY OF PEDAGOGICAL EXEMPLARS

Consider using question-and-answer strategy for learners to come out with the sources of energy and categorise them into renewable and non-renewable sources. Learners can watch videos, have a field trip to sites of renewable energy sources or production and then share their observations with the whole class. In a moderated discussion, learners can discuss the benefits derived from renewable energy sources and how they contribute to the realisation of the SDGs. Consider organising learners' views using concept maps.

ASSESSMENT SUMMARY

Consider using all the assessment modes that encourage learners to express their understanding of the focal areas in this section. Provide learners with a hypothetical energy demand scenario and ask them to propose the most suitable renewable energy source and system for electricity generation. Task learners to research and prepare a presentation on the environmental impact and sustainability aspects of electricity generation from water, wind, solar, biomass, and biogas. This can be used for their summative assessment. Learners can be put into two groups to debate on the topic "renewable energy has improved the global energy security". Learners can discuss the role of international collaboration and partnerships in promoting the widespread adoption of renewable energy and achieving the SDGs' objectives related to global partnerships for sustainable development. This can be used for their formative assessment.

Week 10

Learning Indicator(s):

1. *List the sources of renewable energy*
2. *Explain how renewable energy sources benefit humanity and contribute towards the attainment of the SDGs*

Theme or Focal Area 1:

Renewable energy refers to energy derived from naturally replenished sources, such as sunlight, wind, water, and geothermal heat. Unlike fossil fuels, which are finite and produce harmful emissions when burned, renewable energy sources offer sustainable and cleaner alternatives to meet our energy needs. The importance of renewable energy lies in its ability to address environmental challenges, reduce greenhouse gas emissions, combat climate change, and promote energy security by diversifying our energy mix.

1. **Solar Energy**: Solar energy is one of the most prominent renewable energy sources. It harnesses the sun's rays to generate electricity through photovoltaic cells, commonly known as solar panels. These solar panels contain semiconductor materials, typically made of silicon, which absorb sunlight and release electrons, creating an electric current.

Figure 59: A picture of a Solar Generation Station

Source: lens.google.com, url: https://shorturl.at/itvJS, [accessed: 22.03.2024]

2. **Wind Energy:** Wind energy is another important renewable energy source that harnesses the kinetic energy of the wind to generate electricity. Wind turbines, commonly found in wind farms, are designed to capture the energy of the moving air.

Figure 60: A picture of a Wind Energy Turbine

Source: lens.google.com, url: https://shorturl.at/ouxIO, [accessed: 22.03.2024]

3. **Hydroelectric Power:** In the Hydroelectric Power generation, the rotating turbine shaft is connected to a generator. As the turbines spin, the generator converts the mechanical energy into electrical energy through electromagnetic induction, producing electricity. Hydroelectric power relies on the continuous flow of water, which is replenished by rainfall and snowmelt, making it a renewable energy source.

Figure 61: A picture of a Hydro Energy Generation Station

Source: lens.google.com, url: https://shorturl.at/inQX9, [accessed: 22.03.2024]

4. **Biomass Energy:** Biomass energy is derived from organic matter such as agricultural residues, forestry waste, and energy crops. It involves converting the chemical energy stored in biomass into usable heat, electricity, or biofuels.

Figure 62: A picture of a Biomass Energy Generation Station

Source: lens.google.com, url: https://shorturl.at/zCGKQ, [accessed: 22.03.2024]

5. **Geothermal Energy:** Geothermal energy is heat extracted from the earth's internal sources, primarily from the natural radioactive decay of elements like uranium, thorium, and potassium, as well as from the residual heat from earth's formation.

Figure 63: A picture of a Geothermal Energy Generation Station

Source: lens.google.com, url: https://shorturl.at/rGHUY, [accessed: 22.03.2024]

6. **Tidal and Wave Energy:** Tidal and wave energy are renewable sources that harness the kinetic energy of ocean movements, primarily tides and waves.

Figure 64: A picture of a Tidal Energy Generation Station

Source: lens.google.com, url: https://shorturl.at/kyzEZ, [accessed: 22.03.2024]

Learning Task

1. Guide learners to list the various renewable energy sources
2. Discuss with learners why hydropower is considered a sustainable source of energy.
3. Discuss with class how solar energy work to generate electricity
4. Explore renewable energy sources that can be used for heating homes.
5. Discuss some challenges or limitations of using biomass as a renewable energy source?
6. Consider the case of providing solar energy for a house. Guide learners to size solar energy for home consumption.

7. Facilitate learners trip to a power generating plant and appraise themselves of the process in power generation. Where that is not possible, let learners watch a video of power generation from different plants types.

Theme or Focal Area 2:

The Sustainable Development Goals (SDGs) are a set of 17 global objectives adopted by the United Nations in 2015, with the aim of addressing various interconnected challenges facing humanity and the planet. These goals were designed to guide efforts towards achieving a more sustainable and equitable future for all by 2030. The SDGs cover a wide range of issues, including poverty, hunger, health, education, gender equality, clean water, climate action, and more. They serve as a universal call to action, encouraging governments, businesses, civil society, and individuals to work collaboratively to create a better world.

Significance of the SDGs in Addressing Global Challenges:

The SDGs are crucial in addressing global challenges because they provide a comprehensive and integrated framework for sustainable development. By focusing on interconnected issues, such as poverty, inequality, environmental degradation, and climate change, the SDGs recognise that tackling one problem often requires addressing its root causes and considering the broader implications.

Goals Related to Affordable and Clean Energy (SDG 7) and Sustainable Cities and Communities (SDG 11):

SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. It targets improving energy efficiency, expanding renewable energy sources, and enhancing international cooperation in the energy sector. Access to clean and affordable energy is essential for eradicating poverty, supporting economic development, and promoting sustainable growth.

SDG 11 focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. It addresses the challenges of urbanisation and aims to provide access to adequate and affordable housing, sustainable transportation, green spaces, and improved urban planning.

1. **Environmental Benefits of Renewable Energy:** Renewable energy sources, such as solar, wind, and hydropower, offer significant environmental benefits. Unlike fossil fuels, which release greenhouse gases (GHGs) such as carbon dioxide when burned, renewable energy sources do not produce direct GHG emissions during operation. This plays a crucial role in mitigating climate change, as reducing GHG emissions is vital to limit global warming and its associated impacts, such as extreme weather events, rising sea levels, and disruptions to ecosystems.
2. **Transitioning from Fossil Fuels to Renewables:** Transitioning from fossil fuels to renewable energy sources is imperative for protecting ecosystems and conserving biodiversity. Fossil fuel extraction and consumption have led to habitat destruction, water pollution, and ecosystem degradation. By minimising our reliance on fossil fuels, we can reduce these negative impacts and preserve vulnerable ecosystems, allowing nature to recover and flourish.
3. **Energy Access and Equity:** Renewable energy plays a crucial role in providing access to clean and affordable energy, especially for remote or underserved communities. Many remote areas lack access to centralised power grids, making it difficult for them to benefit from traditional energy sources. In such cases, decentralised renewable energy systems, like off-grid solar panels or small wind turbines, can offer a viable and sustainable solution.
4. **Economic Opportunities and Job Creation:** The transition to renewable energy offers significant economic opportunities and job creation potential. As the renewable energy sector expands, it generates employment across various stages, from manufacturing and installation

to maintenance and research. This job growth stimulates local economies and contributes to overall economic development.

a. **Job Creation:** The renewable energy sector is a significant source of job creation. Developing and operating renewable energy projects requires a diverse range of skills, from engineering and manufacturing to installation and maintenance.

b. **Local Entrepreneurship:** The transition to renewable energy opens opportunities for local entrepreneurs to enter the market. Solar panel installation companies, wind turbine manufacturers, and biomass energy producers are examples of businesses that can thrive in a renewable energy-focused economy.

c. **Investment Opportunities:** Renewable energy projects attract significant investments from various sources, including governments, private investors, and international organisations. These investments contribute to the growth of the renewable energy sector and can lead to attractive returns for investors.

5. **Green Industries and the Transition to a Green Economy:**

a. **Innovation and Technological Advancements:** Investing in renewable energy technologies drives innovation, leading to the development of more efficient and cost-effective solutions.

b. **Green Job Market:** As green industries expand, there will be an increasing demand for professionals in various fields such as renewable energy engineering, environmental sciences, sustainable architecture, and green finance.

c. **Export and Trade Opportunities:** Countries that excel in renewable energy technologies and infrastructure can become leaders in exporting clean energy solutions.

6. **Energy Security and Independence:**

a. Reduced Dependence on Fossil Fuel Imports: Relying on renewable energy sources reduces a country's dependence on fossil fuel imports.

b. Price Stability: Renewable energy sources such as wind, solar, and hydropower have stable and predictable costs over the long term.

7. **Decentralised Renewable Energy Systems:**

a. **Resilient and Reliable Power Supply:** Decentralised renewable energy systems, such as distributed solar panels, small wind turbines, and microgrids, can enhance energy resilience and reliability. By generating power locally, these systems reduce the vulnerability of energy infrastructure to natural disasters, extreme weather events, and cyberattacks, ensuring continuous electricity supply even during emergencies.

b. **Access to Energy in Vulnerable Regions:** Many remote and vulnerable regions lack access to centralised power grids. Decentralised renewable energy systems offer a viable solution to provide electricity to these areas, empowering communities and enabling economic development without relying on extensive and expensive grid infrastructure.

8. **Health and Well-being:**

a. **Air Pollution Reduction:** Renewable energy sources produce little to no harmful air pollutants or greenhouse gas emissions during operation.

b. **Improved Quality of Life:** Cleaner air and a healthier environment contribute to an overall improvement in the quality of life for communities. Reduced pollution levels mean fewer healthcare costs related to respiratory illnesses and improved productivity due to a healthier workforce.

9. **Sustainable Development in Urban Areas:**

a. **Rooftop Solar Panels:** Integrating rooftop solar panels into urban areas allows buildings to generate their electricity and reduce their reliance on the grid.

b. **Smart City Initiatives:** By adopting renewable energy solutions and incorporating advanced energy management systems, cities can optimise their energy use, reduce carbon footprints, and create a more sustainable and liveable environment for residents.

Learning Task

1. Discuss how renewable energy solutions can help developing countries leapfrog traditional fossil-fuel-based energy systems and accelerate progress towards achieving the SDGs.
2. Discuss how investing in renewable energy infrastructure can promote sustainable economic development and create resilient communities, in line with the SDGs' aim of reducing inequalities.
3. Describe the potential environmental benefits of renewable energy sources in terms of land use, water conservation, and biodiversity conservation, with reference to the SDGs' focus on responsible consumption and production.

Pedagogical Exemplars

1. **Managing talk-for-learning:** In a moderated discussion, learners mention the sources of energy and categorise them into renewable and non-renewable sources.
2. **Experiential learning:** Learners watch videos on renewable energy sources and share their observations with the whole class
3. **Experiential learning:** Learners visit a renewable energy site and discuss operations and challenges with site managers and then share their experiences in class through oral, report and power point presentation.
4. **Enquiry-based learning:** Learners research on the state-of-the-art installations of renewable energy and make presentations in class.

Key Assessment

Level 1 Recall formative

1. What is renewable energy?
2. Name two sources of renewable energy.
3. What makes renewable energy different from non-renewable energy?
4. Why is it important to use renewable energy sources?
5. Give an example of renewable energy used in the community.
6. What are the environmental benefits of using renewable energy?
7. How do renewable energy sources help reduce greenhouse gas emissions?
8. Which renewable energy source is most used for generating electricity?
9. What is the main advantage of using wind energy to generate electricity?
10. Explain why hydropower is considered a sustainable source of energy.
11. How does solar energy work to generate electricity?
12. Can you name a renewable energy source that can be used for heating homes?
13. What are some challenges or limitations of using biomass as a renewable energy source?
14. How can the use of renewable energy contribute to energy security in a country?

Level 2 Skills of conceptual understanding: formative

1. Describe three specific renewable energy sources and explain how they benefit humanity by contributing to the reduction of greenhouse gas emissions.

2. Describe the potential environmental benefits of renewable energy sources in terms of land use, water conservation, and biodiversity conservation, with reference to the SDGs' focus on responsible consumption and production.
3. How can the integration of renewable energy technologies into existing energy grids help address climate change and support climate action as outlined in the SDGs?
4. Discuss the role of international collaboration and partnerships in promoting the widespread adoption of renewable energy and achieving the SDGs' objectives related to global partnerships for sustainable development.

Level 3 Strategic Thinking

1. How do renewable energy technologies, such as solar panels and wind turbines, support the SDGs by promoting economic growth and creating job opportunities?
2. Explain the relationship between the adoption of renewable energy and the improvement of global energy security, with reference to the United Nations' Sustainable Development Goals.
3. Describe the positive impact of using renewable energy sources on public health and well-being in urban and rural areas, considering the SDGs' focus on health and well-being for all.
4. How do renewable energy projects contribute to poverty alleviation and access to affordable, reliable, and sustainable energy, aligning with the objectives of the SDGs?
5. Explain how renewable energy solutions can help developing countries leapfrog traditional fossil-fuel-based energy systems and accelerate progress towards achieving the SDGs.
6. Explain how investing in renewable energy infrastructure can promote sustainable economic development and create resilient communities, in line with the SDGs' aim of reducing inequalities.

Week 11

Learning Indicator:

1. *Explain how electricity is generated from water, wind, solar, biomass, and biogas energy sources.*
2. *Compare the electricity generation from the various renewable energy sources with respect to availability of resource, quantity of electricity that could be generated, ease of energy generation, cost of generation, availability of technology, etc.*

Theme or Focal Area 1:

Renewable energy refers to energy sources that are naturally replenished and are considered sustainable over the long term. Unlike fossil fuels such as coal, oil, and natural gas, which are finite and non-renewable, renewable energy sources can be harnessed without depleting their availability for future generations.

1. Hydroelectric Power Generation:

Hydroelectric power generation harnesses the energy of flowing water to produce electricity. It involves the construction of dams across rivers or other water bodies to create reservoirs, which store large quantities of water at an elevated level. When the water is released from the reservoir, it flows through turbines that convert the potential energy of the falling water into mechanical energy. Subsequently, the turbines are connected to generators that transform the mechanical energy into electrical energy.

Construction of Dams: Dams are constructed in locations with sufficient water flow and height difference to create a significant potential energy. The dam traps water in the reservoir, creating a large and stable water body.

Figure 65: A picture of a hydroelectric dam

Source: lens. google.com, url: https://shorturl.at/huGW2, [accessed: 22.03.2024]

Turbines and Generators: The water released from the reservoir flows through large pipes called penstocks, which direct the water to strike the blades of the turbines. The force of the flowing water causes the turbines to rotate. These turbines are connected to generators, which are responsible for converting the rotational energy of the turbines into electrical energy.

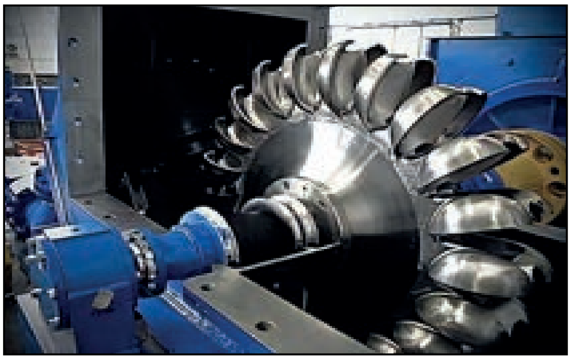


Figure 66: A picture of a hydroelectric turbine

Source: lens.google.com, url: https://shorturl.at/dgltE, [accessed: 22.03.2024]

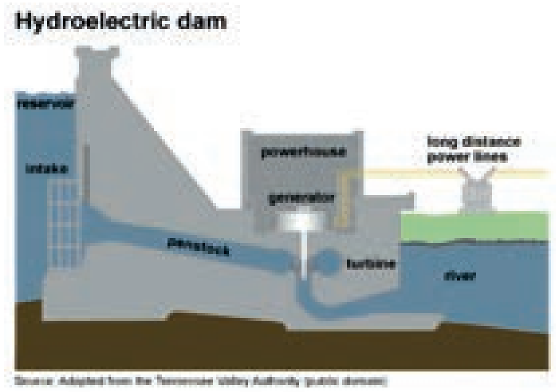


Figure 67: A picture of how hydroelectric energy is generated

Source: US Energy Info Admin, url: https://images.app.goo.gl/2UNPDw1BDytuW98a9, [accessed: 15.04.2024]

2. Wind Energy:

Wind energy is harnessed from the kinetic energy of moving air. Where wind blows strongly, it becomes a major source of energy.

Wind Turbines: Wind turbines consist of large blades mounted on a tower. When the wind blows, it causes the blades to rotate. Wind turbines are used to capture the wind's energy and convert it into electrical energy through the rotation of their blades and the operation of a generator.

Figure 68: A picture of a wind turbine

Source: lens.google.com, url: https://shorturl.at/epMRV, [22.03.2024]

The basic working principle of wind turbines involves three main components: the blades, the shaft, and the generator. When the wind blows, it causes the blades to rotate around the shaft. This rotation creates mechanical energy. The shaft is connected to a generator, which converts the mechanical energy into electricity.

Generator: The rotating blades are connected to a generator, which converts the kinetic energy of the wind into the mechanical energy of the rotating blades into electrical energy.

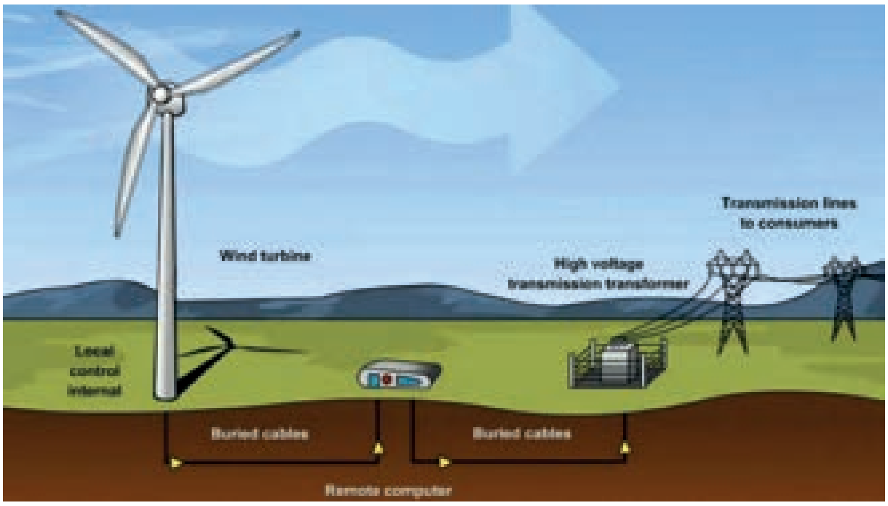


Figure 69: A picture of how wind energy is generated

Source: Morgan King, url: https://images.app.goo.gl/SadgCxyXzR6tPQhQ8 , [Accessed: 15.04.2024]

3. Solar Energy:

Figure 70: A picture of solar panel

Source: lens.google.com, url: https://shorturl.at/aloO9, [22.03.2024]

Solar energy is obtained from the sun's radiation and can be converted into electricity through two main technologies: photovoltaic (PV) and solar thermal systems.

Photovoltaic (PV) Technology: Solar panels, made of semiconductor materials such as silicon, convert sunlight directly into electricity through the photovoltaic effect.

Concentrated Solar Power (CSP) plants use mirrors to focus sunlight onto a receiver, which generates steam to drive turbines and produce electricity.

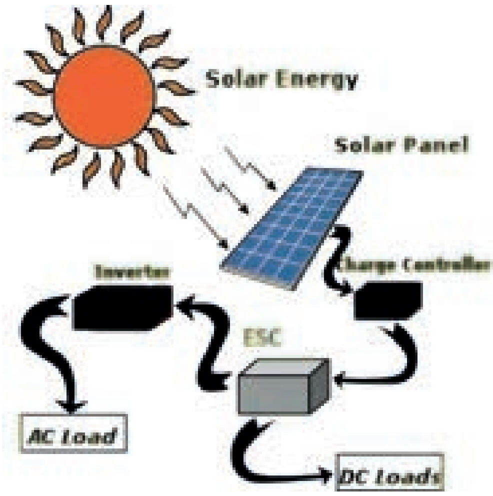


Figure 71: A picture of how solar energy is generated

Source: ICONCE, url: https://images.app.goo.gl/9xFeAYDrp39KwnWB6 , [accessed: 15.04.2024]

4. Biomass Energy:

Biomass energy is derived from organic matter, including agricultural residues, forestry waste, and energy crops. It can be converted into biogas or burned to generate steam, which is then used to drive turbines for electricity production.

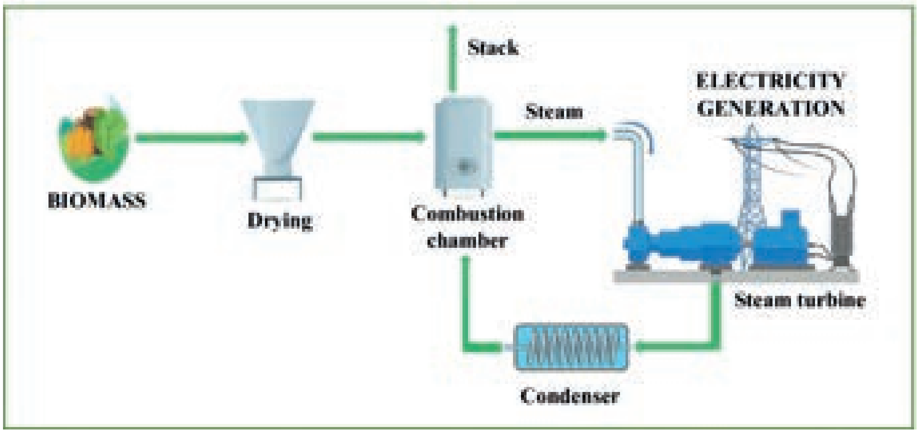


Figure 72: A picture of how biomass energy is generated

Source: Springerlink, url: https://images.app.goo.gl/6brGpjiCd1CVsk9i8 , [15.04.2024]

5. Biogas Energy:

Biogas is produced through the anaerobic digestion of organic waste materials, such as food scraps, agricultural waste, and animal manure. It mainly consists of methane and can be used as a fuel for generating electricity in gas turbines or combustion engines.

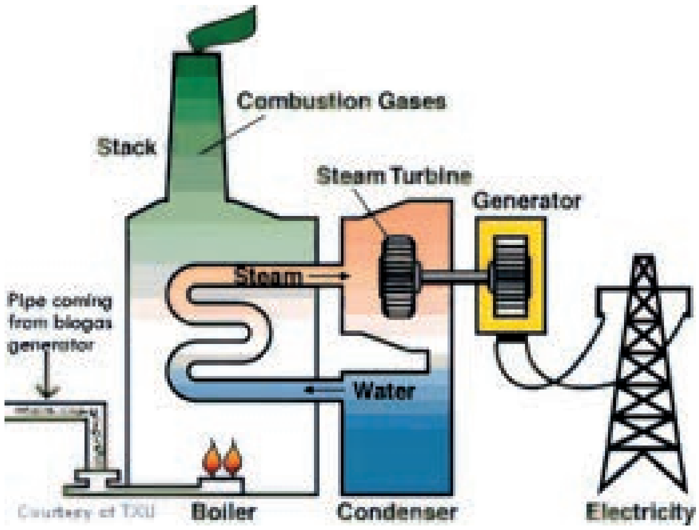


Figure 73: A picture of how biogas energy is generated

Source: springer, url: https://shorturl.at/ikmUY, [22.03.2024]

6. Tidal Energy:

Tidal energy is a form of renewable energy that harnesses the kinetic energy of ocean tides and currents to generate electricity. It is a type of marine energy technology that takes advantage of the predictable and reliable nature of tidal movements. There are two main methods used for generating electricity from tides: tidal stream systems and tidal range systems.

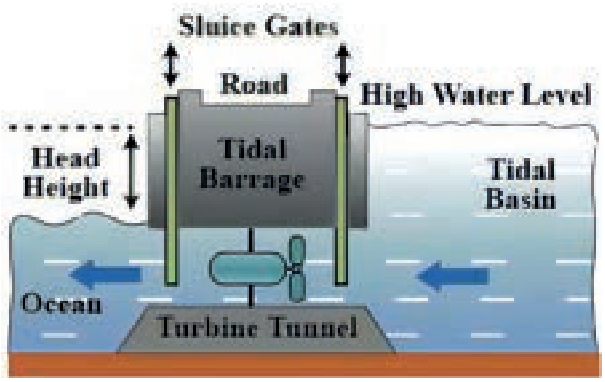


Figure 74: A picture of how tidal energy is generated

Sources: toppr, url: https://images.app.goo.gl/McgPGfFFJXjSv2rF8, [accessed: 15.04.2024]

Learning task

1. Guide learners to list the different sources of renewable energy.
2. Discuss how wind turbines convert the kinetic energy of wind into electrical energy.
3. Discuss the basic principle behind hydropower generation and how it harnesses the energy of flowing water.
4. Evaluate the environmental impacts associated with large-scale hydropower projects, considering both advantages and disadvantages.
5. Discuss the factors that influence the efficiency of wind turbine operation, including wind speed and turbine design.

6. Explore on the photovoltaic (PV) effect and how solar panels use it to convert sunlight into electricity.
7. Compare and contrast solar thermal and solar photovoltaic systems, highlighting their respective working principles and applications.
8. Discuss how resource availability influences the choice of renewable energy for a location.
9. Take a visit to near by power plant and appreciate how the plant functions to produce power.

Theme or Focal Area 2:

It is crucial to compare various renewable energy sources concerning their availability of resources, potential electricity generation, ease of energy production, cost of generation, technological maturity, and other relevant factors. This comparative analysis will help us better understand the strengths and limitations of different renewable energy options, aiding in informed decision-making for a sustainable energy future.

Resource Availability:

1. ***Solar Energy:*** Sunlight is widely available across the globe, with varying intensity based on geographical location and time of day/year. It is abundant in regions close to the equator, but solar panels can be installed in most places, including urban areas with rooftops and solar farms in open spaces.
2. ***Wind Energy:*** Wind resources are location-specific and depend on factors like topography, altitude, and proximity to large water bodies. Windy regions, such as coastal areas and high altitudes, have greater potential for wind energy generation. However, wind turbines can be set up both onshore and offshore, offering flexibility in utilisation.
3. ***Hydroelectric Power:*** Hydroelectric power relies on the availability of water bodies, such as rivers and reservoirs. Regions with significant water flow and elevation changes can harness hydroelectric power effectively. Large-scale projects are often located in specific areas with suitable geography.
4. ***Biomass Energy:*** Biomass resources come from organic materials, including agricultural residues, wood, and dedicated energy crops. It is available in most regions where agricultural and forestry activities occur, making it widespread.
5. ***Biogas Energy:*** Biogas is produced from organic waste, including animal manure, food waste, and sewage. The availability depends on the amount of organic waste generated, making it accessible in both urban and rural areas.
6. ***Tidal Energy:*** Depends on coastal locations with significant tidal movements.

Quantity of Electricity Generation:

1. ***Solar and Wind Energy:*** The energy density of sunlight and wind varies, impacting the potential capacity for electricity generation. Wind turbines can achieve high-capacity factors in windy areas, while solar panels may have lower capacity factors but can be deployed widely.
2. ***Hydroelectric Power:*** Hydroelectric plants can generate significant electricity with high-capacity factors, but the availability is constrained by suitable locations and environmental considerations.
3. ***Biomass and Biogas Energy:*** The quantity of electricity generated from biomass and biogas depends on the availability of feedstock and the efficiency of conversion technologies.
4. ***Tidal Energy:*** Potential is substantial due to predictable and powerful tidal flows.

Ease of Energy Generation:

1. ***Solar Energy:*** Solar installations are straightforward, especially for small-scale applications like rooftop solar panels. Larger solar farms require more planning and land use considerations.
2. ***Wind Energy:*** Wind turbines require specialised infrastructure and careful siting to maximise wind exposure, but they are mature technologies.
3. ***Hydroelectric Power:*** Large-scale hydroelectric projects involve complex engineering and environmental considerations, while small-scale installations may be simpler.
4. ***Biomass and Biogas Energy:*** Generating electricity from biomass and biogas can be simple, especially in decentralised applications.
5. ***Tidal Energy:*** Tidal energy requires specialised infrastructure and can be challenging to implement.

Cost of Generation:

1. ***Solar Energy:*** Solar panel costs have been decreasing in cost, making it more cost-effective over time. Installation and maintenance costs vary based on scale and location.
2. ***Wind Energy:*** Wind turbine costs have also decreased, but installation and maintenance can be expensive, especially for offshore projects.
3. ***Hydroelectric Power:*** **L**arge-scale hydroelectric projects can have high initial costs, but operational expenses are relatively low.
4. ***Biomass and Biogas Energy:*** Costs depend on the availability and transportation of feedstock, and larger projects may be more economically viable.
5. ***Tidal Energy:*** Initial costs can be high due to the harsh marine environment and complex technology.

Availability of Technology:

1. ***Solar and Wind Energy:*** Solar panels and wind turbines are well-established technologies with widespread accessibility.
2. ***Hydroelectric Power:*** Hydroelectric technology is mature, but large-scale projects face challenges due to environmental and social impacts.
3. ***Biomass and Biogas Energy:*** Biomass and biogas technologies are accessible and have various applications, but they require careful management of feedstock.
4. ***Tidal Energy:*** Developing technology with a smaller number of commercial-scale installations.

Learning task

1. Guide learners to list the various considerations in evaluating the choice of renewable energy.
2. Discuss how electricity is generated from the various renewable energy sources (water, wind, solar, biomass, and biogas)
3. Compare the electricity generation from the various renewable energy sources with respect to availability of resources, quantity of electricity that could be generated, ease of energy generation, cost of generation, availability of technology, etc.
4. Discuss the appropriateness of each of the renewable energy sources in terms of resource availability, cost, and quantity of electricity supplied.

5. Invite an engineer from any of the power producing companies to discuss the cost of generating electricity from solar and wind sources. How have technological advancements affected the cost-effectiveness of these renewable energy options?
6. Play a video of the simulation of the working principles of the various energy plants and have learners discuss their observations.
7. Compare the availability of technology for wave energy and solar energy. How does the level of technological development impact the feasibility of harnessing energy from each source?
8. Lead the class to brainstorm the environmental impacts of hydropower and biomass energy generation. How do these impacts vary, and what are the implications for long-term sustainability?
5. Guide learners to evaluate the potential for wind energy and geothermal energy in regions with varying climate conditions. How do climatic factors influence the efficiency and reliability of these energy sources?
6. Discuss the role of government policies in promoting the adoption of renewable energy sources like solar and tidal power. How can policy decisions impact the growth of these industries?

Pedagogical Exemplars

1. **Initiating talk-for-learning:** Through questions and answers learners share their views on processes for generating electricity from water, wind, solar, biomass, and biogas energy sources.
2. **Experiential learning:** Play a video of the simulation of the working principles of the various energy plants and have learners discuss their observations.
3. **Experiential learning:** Play video of the construction of selected renewable energy plant and have learners discuss what they have learned.
4. **Experiential learning:** Learners visit a renewable energy generation plant and discuss their questions with site engineers.
5. **Enquiry-Based learning:** Have learners research on the mechanisms of the various energy generation plants, such as solar, wind, etc; their advantages and disadvantages as well as their environmental impacts.
6. **Project-based learning**: Learners are put in different task groups and tasked to research into how to design a power plant to generate energy from various sources. Groups share their findings with the whole class.
7. **Mixed ability/gender groups:** In groups, learners are given a company each to research on their manufacturing of electricity generation systems for renewable energy sources. Groups share their findings with the whole class.
8. **Managing talk-for-learning:** In different task groups, learners discuss the availability of resources, quantity of electricity that could be generated, ease of energy generation, cost of generation, and availability of technology for various electricity generation systems for renewable energy.

Key Assessment

Level 1:

1. What is renewable energy?
2. Mention five (5) sources of renewable energy.
3. Explain how electricity is generated from solar, wind, hydro, tidal, energy etc.
4. Mention two (2) limitations or challenges that may arise when utilising water to generate electricity.

Level 2 Skills and Conceptual Understanding

1. What are the primary advantages of using wind for electricity generation compared with traditional fossil fuels?
2. Describe some limitations or challenges that may arise when utilising water to generate electricity. How can these challenges be addressed?
3. What are the primary advantages of using the sun for electricity generation compared with traditional fossil fuels?

Level 3 Strategic Thinking

1. Provide learners with a hypothetical energy demand scenario and ask them to propose the most suitable renewable energy source and system for electricity generation.
2. Ask learners to research and prepare a presentation on the environmental impact and sustainability aspects of electricity generation from water, wind, solar, biomass, and biogas.
3. Investigate the integration of renewable energy systems into the existing power grid and discuss the challenges and opportunities for large-scale adoption.

Section 5 Review

1. Will learners be able to list the sources of renewable energy?
2. Will learners be able to explain how renewable energy benefits and contributes towards the attainment of the SDGs?
3. Can learners explain how electricity is generated from the various renewable energy sources?
4. Will learners be able to compare electricity generation from renewable energy with respect to availability of resources, quantity of generation, etc.?

Further Reading

- Theraja, B. L., & Theraja, A. K. (1999). A textbook of Electrical Technology in SI Units. *AC & DC machines*, *2*.

Teaching/Learning Resources

1. Projector
2. Laptop, and videos on renewable energy sources.
3. Videos on electricity generation from renewable energy sources.
4. Whiteboard, and marker

References

1. Hiley, J., Brown, K. E., & Hughes, E. (2001). Hughes Electrical & Electronic Technology- either edition.
2. Theraja, B. L., & Theraja, A. K. (1999). A textbook of Electrical Technology in SI Units. *AC & DC machines*, *2*.

SECTION 6: ENERGY EFFICIENCY AND CONSERVATION

Strand: **Energy Systems**

Sub-strand: Energy Efficiency and Conservation

Learning Outcome: *Use various instruments to measure electrical and non-electrical quantities in renewable energy systems*

Content Standard: Develop the skill to measure, estimate, and analyse energy production and consumption in renewable energy systems

INTRODUCTION AND SECTION SUMMARY

This section introduces learners to various measuring instruments used to measure electrical and non-electrical quantities. Measuring instruments are devices or tools used to quantify and assess various physical parameters in a systematic and accurate manner. These instruments are essential in renewable energy systems as they enable the monitoring, control and optimisation of various electrical and non-electrical quantities. Their role is critical in ensuring the efficient and reliable operation of renewable energy systems, which leads to increased energy production and reduced environmental impact. Accurate measurements are crucial for the evaluation, maintenance and optimisation of electrical and non-electrical systems. Nameplates are essential identification labels affixed to equipment and machinery. They serve the purpose of providing crucial information about the equipment, ensuring proper use, maintenance and safety. Nameplates are typically made of durable materials, like metal or plastic, to withstand harsh environments and last throughout the equipment's lifespan. Energy consumption refers to the amount of energy used by various appliances, devices, equipment, or systems over a specific period. It plays a crucial role in residential, commercial, and industrial settings as it directly impacts costs, environmental sustainability, and overall efficiency. Understanding energy consumption is essential to make informed decisions about energy usage and conservation.

The weeks covered by the section are:

Week 12: Measurement and Instrumentation

Week 13: Engineering Specifications

SUMMARY OF PEDAGOGICAL EXEMPLARS

Various pedagogies should be used to bring out the creativity in the learners. Consider talk-for-learning, experiential learning, collaborative learning and enquiry-based learning. In a moderated discussion, learners discuss electrical and non-electrical parameters in renewable energy systems that require measurement and indicate the instrument that could be used. Provide learners with some instruments to observe and share their observation with the class. Learners can visit various renewable energy systems sites or watch videos of it and perform measurements of electrical and non-electrical quantities with teachers' guidance.

ASSESSMENT SUMMARY

Vary the assessment modes and strategies to suit all categories of learner for them to express their knowledge and understanding of the major themes in this section. Provide an example of a non-electrical quantity that might need measurement in a renewable energy system. Consider using multiple-choice questions that ask learners to identify basic instruments commonly used in renewable energy systems for electrical and non-electrical measurements. Learners can be tasked to design an experiment to compare the effectiveness of different instruments in measuring a specific quantity in a renewable energy context. Learners can analyse the impact of internal resistance on the accuracy of an ammeter when measuring current. Consider tasking learners to research and explain the working principle of a lux meter and its use in measuring illumination.

Week 12

Learning Indicator(s):

1. *List instruments used for measuring electrical and non-electrical quantities in renewable energy systems*
2. *Use various instruments to accurately measure electrical and non-electrical quantities*

Theme or Focal Area 1:

Measurement instruments are devices or tools used to quantify and assess various physical parameters in a systematic and accurate manner. These instruments are essential in renewable energy systems as they enable the monitoring, control, and optimisation of various electrical and non-electrical quantities. Their role is critical in ensuring the efficient and reliable operation of renewable energy systems, which leads to increased energy production and reduced environmental impact.

The Importance of Measurement Instruments in Renewable Energy Systems:

1. **Performance Monitoring**: Measurement instruments enable the continuous monitoring of key parameters, allowing operators to track the performance of the renewable energy system in real-time.
2. **Fault Detection**: By measuring various parameters, these instruments can identify and diagnose issues or faults in the system promptly, facilitating rapid troubleshooting and maintenance.
3. **Efficiency Optimisation**: Accurate measurement data help operators make informed decisions to optimise the system's efficiency, leading to better energy generation and utilisation.
4. **Safety Assurance**: Measurement instruments play a crucial role in ensuring the safe operation of renewable energy systems by monitoring safety-critical parameters.

Electrical Measurement Instruments:

1. **Voltmeters:** Voltmeters measure voltage, which represents the potential difference between two points in an electrical circuit. They are crucial for assessing the electrical potential and voltage variations in renewable energy systems.

Figure 75: A picture of a Voltmeter

Source: lens.google.com, url: https://shorturl.at/rwBS6, [accessed: 22.03.2024]

2. **Ammeters**: Ammeters measure electrical current flowing through a circuit, expressed in amperes (amps). They help monitor current levels and identify potential overloads or abnormal currents.

Figure 76: A picture of an Ammeter

Source: lens.google.com, url: https://shorturl.at/ouD29, [accessed: 22.03.2024]

3. **Wattmeters*:*** Wattmeter's measure the real power (in watts) consumed by electrical loads. They are essential for determining the energy consumption of various components in the system.

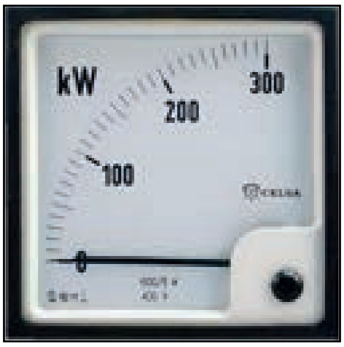


Figure 77: A picture of a Wattmeter

Source: tescaglobal, url: https://shorturl.at/acoT6, [accessed: 22.03.2024]

4. **Power Analysers**: Power analysers are advanced instruments that measure various electrical parameters such as voltage, current, power factor, harmonics, and energy. They provide comprehensive insights into system performance and efficiency.

Figure 78: A picture of a Power Analyser

Source: google.com, url: https://shorturl.at/iJLNZ, [accessed: 22.02.2024]

5. **Energy Meters*:*** Energy meters measure the total electrical energy consumed by a load or generated by a renewable energy system over a specific period, typically in kilowatt-hours (kWh).

Figure 79: A picture of an Energy meter

Source: gettyimages.com, url: https://shorturl.at/nrt13, [accessed: 22.03.2024]

Non-Electrical Measurement Instruments:

1. **Temperature Sensors**: Thermocouples and resistance temperature detectors (RTDs) are commonly used to measure temperature in renewable energy systems, providing crucial data for system operation and thermal management.

Figure 80: A picture of a Temperature Sensor

Source: istockphoto.com, url: https://shorturl.at/fiWY8, [accessed: 22.03.2024]

2. **Pressure Sensors**: Pressure sensors measure fluid pressures, such as water pressure in hydropower systems or air pressure in wind turbines.

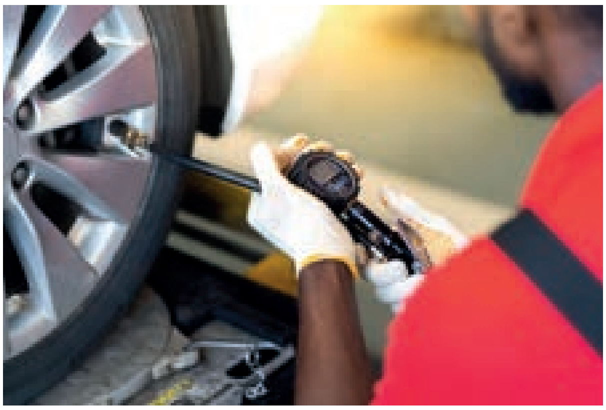


Figure 81: A picture of a Pressure Sensor

Source: istockphoto.com, url: https://shorturl.at/erAQT, [accessed: 22.03.2024]

3. **Humidity Sensors**: Humidity sensors measure the moisture content in the air, which is essential for assessing environmental conditions and potential condensation issues.

Figure 82: A picture of a Humidity Sensor

Source: istockphoto.com, url: https://shorturl.at/prxRS, [accessed: 22.03.2024]

4. **Wind Speed Anemometers**: Anemometers measure wind speed, a critical parameter for wind energy systems, as it directly impacts turbine performance.

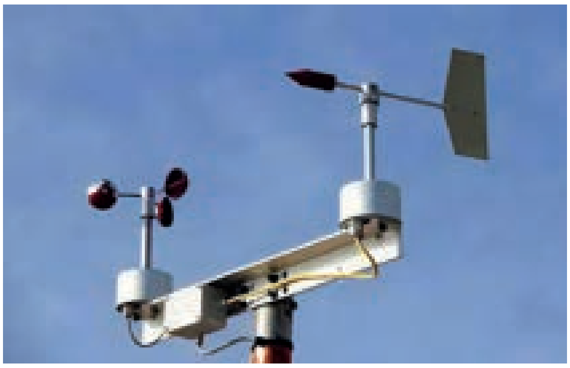


Figure 83: A picture of an Anemometer and Wind Vane

Source: sciencephoto.com, url: https://shorturl.at/tzEHJ, [accessed: 22.03.2024]

5. **Solar Radiation Sensors (Pyranometers)**: Pyranometers measure solar radiation, providing data for solar PV system performance evaluation and potential estimation.

Figure 84: A picture of a Pyranometer

Source: delta-t.co.uk, url: https://shorturl.at/chozC, [accessed: 22.03.2024]

6. **Biomass Fuel Composition Analysers**: In biomass energy systems, fuel composition analysers determine the quality and characteristics of biomass feedstock, affecting combustion efficiency.

Figure 85: A picture of a Biomass Analyser

Source: emi-lda.com, url: https://shorturl.at/cejNR, [accessed: 22.03.2024]

Learning Task

1. Discuss the purpose of using instruments to measure quantities in renewable energy systems.
2. Guide learners to brainstorm on why accurate measurements are important in renewable energy systems.
3. Guide learners to list the difference between electrical and non-electrical quantities in renewable energy systems.
4. Discuss how the variations in non-electrical quantities impact the performance of a renewable energy system?
5. Discuss the potential consequences of using inaccurate instruments in a renewable energy system measurement.
6. Assist learners to handle and examine all available instruments in your lab to appreciate their use in measurement. Where these are not available, watch a video of how instrumentation help in the monitoring and maintenance of energy systems.

Theme or Focal Area 2:

Accurate measurements are crucial for the evaluation, maintenance, and optimisation of electrical and non-electrical systems.

Instrument Familiarisation: Instruments like voltmeters, ammeters, Wattmeter, and multimeters have display panels, knobs, probes, and connectors that allow us to obtain and analyse data. Learning how to handle, set up, and use these instruments correctly is essential for accurate measurements.

Measurement Units and Scales: Every measurement is associated with specific units and scales. Understanding these units and scales is crucial for representing measured quantities accurately. We will explore units such as volts, amperes, watts, ohms, degrees Celsius, pascals, meters per second, lux, and sieverts.

Electrical Quantity Measurement: To get hands-on experience with instruments like voltmeters, which measure voltage; ammeters, which measure current; Wattmeter, which measure power; and multimeters, which can measure various electrical parameters simultaneously. You will learn how to measure voltage, current, power, resistance, and other electrical parameters using these instruments.

Non-Electrical Quantity Measurement: Renewable energy systems involve measuring various non-electrical quantities too. Instruments such as thermometers, pressure gauges, anemometers, lux meters, and radiation detectors are essential for this purpose. We will conduct practical exercises to measure temperature, pressure, wind speed, illuminance, and radiation levels.

Calibration and Zero Adjustment: To ensure accurate measurements, instruments need to be calibrated regularly. We will teach you the importance of calibration and how to perform zero adjustments according to instrument specifications. Calibrated instruments provide reliable and consistent readings.

Measurement Techniques: Accurate measurements rely on proper measurement techniques. We will explain best practices for probe placement, connections, and signal acquisition procedures. Following these techniques will help you obtain precise and repeatable readings.

Troubleshooting and Error Analysis: Measurement errors can occur, and it's essential to identify and rectify them. We will provide opportunities for you to troubleshoot measurement errors and guide you in identifying potential sources of errors. Implementing corrective measures will ensure reliable measurements.

Safety Considerations: Safety is paramount when using measurement instruments, especially in electrical applications. We will emphasise proper handling, electrical safety precautions, and the use of personal protective equipment to ensure your safety during experiments and measurements.

Collaborative Projects: Learners should be engaged in collaborative projects where they use measurement instruments to collect and analyse data related to renewable energy systems. These projects will promote teamwork, problem-solving, and critical thinking skills.

Learning Task

1. Assist learners to identify all measuring instruments used for renewable energy systems.
2. Discuss why it is important to ensure that an electrical circuit is switched off before connecting a measuring instrument?
3. Demonstrate to learners the wearing of safety equipment while making electrical measurements.
4. Discuss with learners why it is important to handle electrical instruments with dry hands.

5. Assist learners to list examples of non-electrical quantities that can be measured using appropriate instruments.
6. Assist learners to experiment measurement of electrical and non-electrical quantities using various instruments.
7. Discuss how the various instruments work and the quantities they measure
8. Discuss the impact of internal resistance on the accuracy of an ammeter when measuring current.

Pedagogical Exemplars

1. **Managing talk-for-learning:** In a moderated discussion, learners discuss electrical and non-electrical parameters in renewable energy systems that require measurement and indicate the instrument that could be used.
2. **Initiating talk-for-learning:** The facilitator presents a comprehensive list of electrical and non-electrical quantities in energy systems that require measurement and the associated instruments for measurement.
3. **Experiential learning**: Learners inspect the various instruments and practice using them in the lab.
4. **Experiential learning:** Learners visit various renewable energy systems to interact with engineers on site and learn how measurements are taken; or watch videos of same measurements of electrical and non-electrical quantities with teachers' guidance.

Key Assessment

Level 1 Recall

1. List the instruments used for measuring electrical and non-electrical quantities in renewable energy systems.
2. What is the purpose of using instruments to measure quantities in renewable energy systems?
3. Name one instrument used to measure electrical quantities in renewable energy systems?
4. Provide an example of a non-electrical quantity that might need measurement in a renewable energy system.
5. Explain why accurate measurements are important in renewable energy systems.
6. What is the difference between electrical and non-electrical quantities in renewable energy systems?
7. Present learners with images of instruments used in renewable energy systems and ask them to label each instrument correctly.
8. Task learners to categorise instruments based on the type of quantity they measure (electrical or non-electrical) and explain their functions.
9. Ask learners to recall specific examples of how different instruments are deployed to monitor and measure renewable energy system parameters.

Level 2 Skills of conceptual understanding:

1. Compare and contrast instruments used for measuring electrical and non-electrical quantities in renewable energy systems.
2. Describe the role of instruments in maintaining the efficiency of a renewable energy system.

3. How do variations in non-electrical quantities impact the performance of a renewable energy system?
4. List and explain at least three advantages of using instruments to measure renewable energy system parameters.
5. Explain the potential consequences of using inaccurate instruments in a renewable energy system.

Level 3 Strategic reasoning:

1. Analyse the technological advancements in instruments used for measuring electrical quantities in modern renewable energy systems.
2. Evaluate the environmental impact of inaccurate measurements in a renewable energy system.
3. Design an experiment to compare the effectiveness of different instruments in measuring a specific quantity in a renewable energy context.
4. Discuss the limitations of a digital multimeter when measuring rapidly changing electrical signals.
5. Explain how temperature can affect the accuracy of certain electrical measurement instruments.
6. Analyse the impact of internal resistance on the accuracy of an ammeter when measuring current.
7. Describe sources of error that can lead to inaccuracies in electrical measurements.
8. Explain how systematic and random errors differ in the context of measurement.
9. If an ammeter reads 2.5 A while the actual current is 2.0 A, calculate the percentage error and suggest reasons for the discrepancy.
10. Explore the principles behind an oscilloscope and its applications in measuring electrical signals.
11. Describe how a digital thermometer differs from a traditional mercury thermometer, highlighting their mechanisms and benefits.
12. Research and explain the working principle of a lux meter and its use in measuring illumination

Week 13

Learning Indicator(s):

1. *Extract data from nameplates of equipment*
2. *Compute and/or interpret energy consumption from nameplates*

Theme or Focal Area 1:

Nameplates are essential identification labels affixed to equipment and machinery. They serve the purpose of providing crucial information about the equipment, ensuring proper use, maintenance, and safety. Nameplates are typically made of durable materials, like metal or plastic, to withstand harsh environments and last throughout the equipment's lifespan.

Figure 86: A picture of a Nameplate

Source: promnicek.live/product, url: https://shorturl.at/tGMU3, [accessed: 22.03.2024]

The Significance of Nameplates on Equipment:

1. **Identification:** Nameplates help identify the equipment, distinguishing it from other similar items within a facility or industry.
2. **Information:** They display vital technical details, making it easier for operators, maintenance personnel, and engineers to understand the equipment's capabilities and limitations.
3. **Safety:** Nameplates often include safety symbols and warnings, alerting users to potential hazards and safety precautions.
4. **Compliance:** Many industries have specific regulations and standards requiring certain information to be displayed on nameplates to ensure compliance with safety and environmental guidelines.

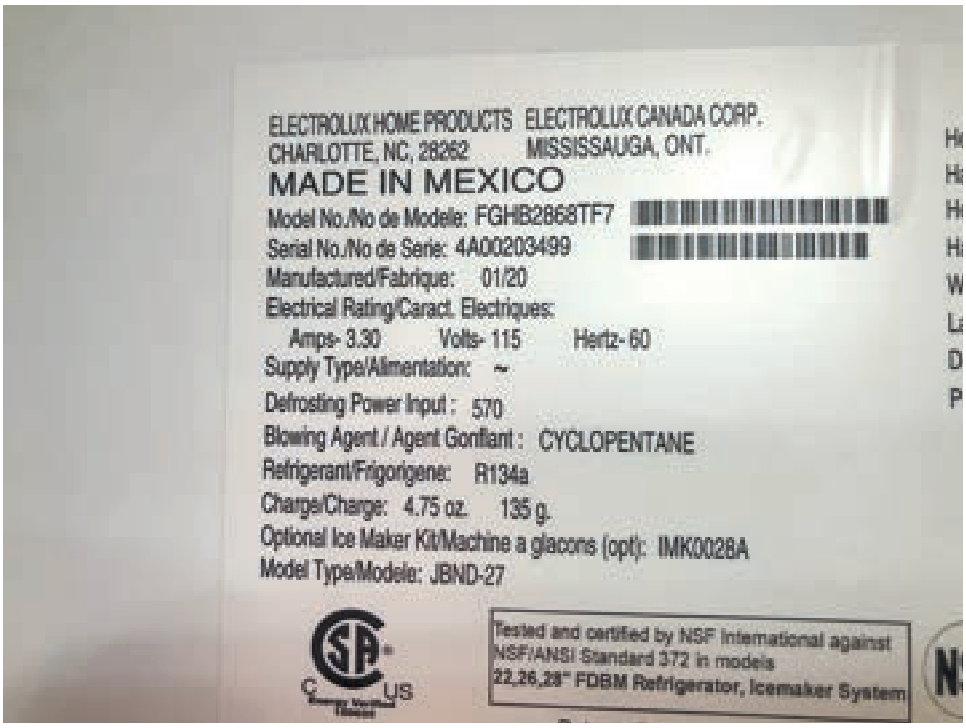


Figure 87: A picture of an appliance Nameplate

Source: ppec.coop, url: https://shorturl.at/imzP7, [accessed: 22.03.2024]

Types of Information Found on Nameplates and Their Importance:

1. **Manufacturer's Name:** The nameplate includes the name or logo of the equipment manufacturer, indicating responsibility for the product. It helps establish the source and reputation of the equipment, ensuring accountability for quality.
2. **Model Number:** The unique identifier is given by the manufacturer to distinguish different versions or configurations of the equipment. It aids in identifying the exact model, which is crucial for obtaining the correct spare parts and technical documentation.
3. **Serial Number:** A unique alphanumeric code assigned to each individual unit for tracking, warranty, and maintenance purposes. It facilitates tracking the equipment's history, maintenance records, and warranty information.
4. **Rating Information:** Details such as voltage rating, current rating, power rating, frequency, capacity, efficiency, and other specifications relevant to the equipment's performance. Provides critical data to ensure the equipment is used within safe operating parameters, preventing damage and accidents.

Nameplate Codes and Symbols:

1. **Electrical Safety Symbols:** Indicate potential electrical hazards and precautions to be taken during operation and maintenance.
2. **Environmental Compliance Symbols**: Display compliance with environmental regulations, such as RoHS (Restriction of Hazardous Substances) and WEEE (Waste Electrical and Electronic Equipment) directives.
3. **Certification Marks:** Symbols representing compliance with specific industry standards or safety certifications.

Nameplate Standards and Regulations:

Various international and industry-specific standards govern the information required on nameplates, ensuring uniformity and adherence to safety guidelines. For example, ISO 3864 provides guidelines for safety signs and colours, while ANSI Z535 sets standards for product safety labels.

Measurement Units:

Common measurement units found on nameplates include volts (V), amperes (A), watts (W), hertz (Hz), kilograms (kg), etc. Understanding these units is essential for evaluating the equipment's performance and compatibility with other systems.

Reading and Recording Data:

When extracting data from nameplates, precision and attention to detail are crucial. Any errors in recording the information could lead to incorrect usage or maintenance, potentially compromising safety and equipment functionality.

Equipment Identification:

Nameplate data helps identify specific equipment, making it easier to locate technical manuals, order spare parts, and access other relevant information, such as maintenance schedules.

Learning task

1. Assist learners to identify the location of the nameplate on a common equipment.
2. Discuss the definition of the term "serial number" as it relates to a nameplate.
3. Suppose you are given a nameplate with information about a machine's power rating, voltage, and current. Guide learners on how to use this data to determine if the equipment is compatible with a specified use?
4. Imagine you oversee maintenance of a set of industrial machines. One of the nameplates has worn off, and you need to identify the missing information. Guide learners to discuss a strategy they could use to recover or verify the data.
5. Compare and contrast the information typically found on the nameplate of an electrical device with that of a mechanical device. Ask learners how the types of information might differ, and why.

Theme or Focal Area 2:

Energy consumption refers to the amount of energy used by various appliances, devices, equipment, or systems over a specific period. It plays a crucial role in residential, commercial, and industrial settings as it directly impacts costs, environmental sustainability, and overall efficiency. Understanding energy consumption is essential to make informed decisions about energy usage and conservation.

Units of Energy Measurement:

The most common unit of energy measurement is the kilowatt-hour (kWh). One kilowatt-hour is equal to using one kilowatt of power for one hour. This unit is widely used because it represents the total energy consumed over time accurately. In some cases, smaller units like watt-hours (Wh) or larger units like megawatt-hours (MWh) or gigawatt-hours (GWh) may also be used, depending on the scale of consumption.

Nameplate Data Relevant to Energy Consumption:

The nameplate of an appliance or equipment typically contains important data relevant to energy consumption. The key parameters to look for include:

1. ***Power Rating:*** This is usually labelled in watts (W) or kilowatts (kW) and represents the maximum power an appliance or equipment consumes when operating at full capacity.
2. ***Voltage Rating:*** Indicates the voltage at which the appliance is designed to operate.
3. ***Current Rating:*** This represents the current in amperes (A) that the appliance draws at its rated voltage.
4. ***Frequency Rating:*** This shows the frequency in hertz (Hz) at which the appliance operates.
5. ***Energy Efficiency*** Rating: Some appliances may also display an energy efficiency rating, such as Energy Star certification, indicating how efficiently they use energy compared to standard models.

Conversion Factors and Formulas for Energy Consumption:

To compute energy consumption (in kWh) using nameplate data, you can use the formula:

Energy Consumption (kWh) = (Power Rating in kW) × (Operating Time in hours)

Example: If a device has a power rating of 1.5 kW and operates for 5 hours:

Energy Consumption = 1.5 kW × 5 hours = 7.5 kWh

Interpreting Power Ratings and Energy Consumption: Power ratings indicate the rate at which energy is used by an appliance. The relationship between power (in watts) and energy (in watt-hours or kilowatt-hours) can be understood as follows:

Power (in watts) = Energy (in watt-hours) ÷ Time (in hours)

Time Period Considerations:

When analysing energy consumption, it's essential to consider the time over which energy is consumed. Instantaneous power (in watts) represents the power consumed at any given moment, while cumulative energy consumption (in watt-hours or kilowatt-hours) represents the total energy used over a specific period.

Calculating Energy Consumption:

Let's consider an example: A refrigerator with a power rating of 150 watts operates for 24 hours a day. To calculate its daily energy consumption:

Energy Consumption (kWh) = (150 watts ÷ 1000) × 24 hours = 3.6 kWh

Real-World Applications:

Example 1:

A washing machine with a power rating of 2 kW is used for 2 hours daily. Calculate its weekly energy consumption.

Solution:

Energy Consumption (kWh) = (2 kW × 2 hours) × 7 days

= 28 kWh

Example 2:

A light bulb with a power rating of 60 watts is used for 4 hours daily. Calculate its monthly energy consumption.

Solution:

Energy Consumption (kWh) = (60 watts ÷ 1000) × (4 hours × 30 days)

= 7.2 kWh

Energy Efficiency:

Energy efficiency refers to how well an appliance or equipment converts input energy into useful output. To compare the energy efficiency of different devices, you can use the formula:

Energy Efficiency (%) = (Useful Output Energy ÷ Input Energy) × 100

Energy Conservation Strategies:

To conserve energy in daily life, students can adopt various strategies, such as:

1. Turning off lights and electrical appliances when not in use.
2. Using energy-efficient appliances and LED light bulbs.
3. Insulating homes to reduce heating and cooling needs.
4. Unplugging chargers and devices when fully charged.

Learning task

1. Assist learners to identify basic information found on nameplates of equipment, such as the manufacturer, model number, serial number, and voltage rating.
2. Discuss with learners the meaning of the symbols and abbreviations found on nameplates of given equipment.
3. Discuss with learners the information found on nameplates of equipment to determine the compatibility of different pieces of equipment.
4. Suppose you are given a nameplate with information about a machine's power rating, voltage, and current. Guide learners on how to use this data to determine if the equipment is compatible with a specific power supply?
5. Guide learners to calculate the power consumption of a piece of equipment from information available on the name plate or datasheet.

Pedagogical Exemplars

Initiating talk-for-learning: Through a question-and-answer session**,** individual learners explain what a nameplate is and its relevance. Learners are presented with nameplates (actual or photographs) of various equipment for them to inspect and share with whole class

Problem-based learning: Learners are provided with nameplates of equipment and asked to write down power, voltage, current, power factor, etc. Learners compute power (if not available) and energy over given periods, say 30 minutes, 1 hour, 2 hours, etc. Learners discuss the computations with whole class. Encourage them to tolerate criticism and respect the views of others.

Key Assessment

Level 1 Recall:

1. What is a nameplate on an equipment, and why is it important to extract data from it?
2. What types of information can you typically find on a nameplate of equipment? Give examples.
3. What is the purpose of extracting data from a nameplate? Provide at least one example of how this data might be useful.
4. Create a list of at least three pieces of information that you might find on a nameplate of a piece of machinery.
5. What does the term "data extraction" mean in the context of nameplates on equipment?

Level 2 Skills of conceptual understanding:

1. Compare the information found on a nameplate with the information available in a user manual for the same equipment. How are they similar, and how are they different?
2. Select one specific piece of information from a nameplate (e.g., serial number) and explain why it is crucial for maintenance and tracking purposes.
3. Imagine you oversee maintaining a collection of machines in a factory. Explain the step-by-step process to be followed to extract and record data from the nameplates for proper maintenance scheduling.
4. If a nameplate is faded and hard to read, describe at least two methods that could be used to extract the necessary data accurately.
5. Why is it important to update and cross-check the extracted data from nameplates regularly? How might outdated or incorrect information impact equipment performance and safety?

Section 6 Review

1. Can learners list instruments used to measure electrical and non-electrical quantities?
2. Can learners use various instruments to accurately measure electrical and non-electrical quantities?
3. Can learners extract data from nameplate of equipment when given one?
4. Will learners be able to compute or interpret energy consumption from nameplates?

Further Reading

- Smith, J. A., (2019). *Industrial Equipment Nameplates: How to Decode and Understand Them*. Engineering Press, New York

Teaching/Learning Resources

1. Projector
2. Laptop, and assorted instruments used to measure electrical and non-electrical quantities in renewable energy systems.

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