

MINISTRY OF EDUCATION
GHANA ASSOCIATION OF
SCIENCE TEACHERS



Engineering

for Senior High Schools

Year 3



Ing. Timothy Alhassan
Ing. Dr. Daniel Opoku
Daniel K. Agbogbo

Reviewed by Dr. Albert Kotawoke Awopone



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Ghana Education
Service (GES)





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FOREWORD

Ghana's new Senior High School Curriculum aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, knowledge, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, progress to further studies and enter the world of work. This is the first time that Ghana has developed a Senior High School 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.

The Ministry of Education is proud to have overseen the production of these Learner Materials which can be used in class and for self-study and revision. These materials have been developed through a partnership between the Ghana Education Service, teacher unions (Ghana National Association of Teachers- GNAT, National Association of Graduate Teacher -NAGRAT and the Pre-Tertiary Teachers Association of Ghana- PRETAG) and National Subject Associations. These materials are informative and of high quality because they have been written by teachers for teachers with the expert backing of each subject association.

I believe that, if used appropriately, these materials will go a long way to transforming our Senior High Schools and developing Ghana so that we become a proud, prosperous and values-driven nation where our people are our greatest national asset.

Haruna Iddrisu MP
Minister for Education

SECTION

1

ENGINEERING PRACTICE IN SOCIETY



ENGINEERING IN SOCIETY

INTRODUCTION

This section will introduce you to the Sustainable Development Goals (SDGs) and how they connect to engineering. The SDGs are 17 goals created in 2015 by all countries in the United Nations to help solve big problems like poverty, inequality, climate change, and environmental damage. These goals aim to make the world a better place by the year 2030. Your quest to be a future engineer and solve real-world problems means you have an important part to play. Engineers help make the world safer and more sustainable by creating new technologies, systems, and infrastructure that support these global goals. Future engineers, scientists, designers, and entrepreneurs like you must think creatively and develop innovative, sustainable solutions to reach the SDGs. These ideas should use science and technology and consider what people, and the planet need.

KEY IDEAS

- **Community and Global Impact:** Engineering is not just about machines or buildings; it is about improving lives. When you understand the SDGs and apply engineering thinking, you can help make both local communities and the world more sustainable and inclusive.
- **Engineering and the SDGs:** Engineering plays a crucial role in achieving many SDGs. For example, solar energy systems support SDG 7 (Affordable and Clean Energy), while improved sanitation designs support SDG 6 (Clean Water and Sanitation).
- **Problem-Solving Through Innovation:** Engineers use creativity, science, and technology to solve real-life problems. You will explore and propose engineering ideas that help achieve the SDGs in their communities.
- **Role of Engineering in Society:** Engineers design and build solutions that help people live better lives. Their work supports economic growth, protects the environment, and improves access to essential services like clean water, safe housing, and renewable energy.
- **Sustainable Development Goals (SDGs):** The SDGs are 17 global goals set by the United Nations to help make the world a better place by addressing issues such as poverty, clean energy, good health, clean water, and climate change.

SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals (SDGs) are 17 global goals created by the United Nations in 2015. They are part of a worldwide plan called the 2030 Agenda for Sustainable Development.

The SDGs are meant to help make the world a better and fairer place by the year 2030. They focus on solving big problems like: Poverty, Inequality, Climate change, Pollution and environmental damage, Peace and justice.

These goals are important for protecting people, communities, and the planet so that everyone can live well now and in the future.

Key Features

1. **Integrated and universal:** They apply to all countries, rich and poor.
2. **People-centred:** They are focused on eliminating poverty and hunger, promoting health, education, and gender equality.
3. **Planet-friendly:** They are aimed at combating climate change, protecting the environment, and promoting sustainable use of natural resources.
4. **Inclusive growth:** They encourage decent work, innovation, sustainable cities, and reduced inequalities.

The seventeen (17) Sustainable Development Goals (SDGs)

1. **No Poverty**
End poverty in all its forms everywhere.
Meaning: Let us work to end poverty everywhere so that everyone can live a better life.
2. **Zero Hunger**
End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
Meaning: Make sure everyone has enough food and support farming that protects the environment.
3. **Good Health and Well-being**
Ensure healthy lives and promote well-being for all at all ages.
Meaning: Help people live long and healthy lives, with access to good healthcare.
4. **Quality Education**
Ensure inclusive and equitable quality education and promote lifelong learning opportunities.
Meaning: Give all children and adults a chance to learn and reach their full potential.
5. **Gender Equality**
Achieve gender equality and empower all women and girls.
Meaning: Treat everyone equally, including boys and girls, men and women, and give all people the same chances in life.
6. **Clean Water and Sanitation**
Ensure availability and sustainable management of water and sanitation for all.
Meaning: Make clean water and proper toilets available to everyone, everywhere.
7. **Affordable and Clean Energy**
Ensure access to affordable, reliable, sustainable, and modern energy for all.
Meaning: Provide safe, clean, and affordable energy that does not harm the environment.

8. **Decent Work and Economic Growth**

Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work.

Meaning: Create good jobs for people and help the economy grow in a fair and sustainable way.

9. **Industry, Innovation, and Infrastructure**

Build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation.

Meaning: Build roads, buildings, and technology that help people live and work better.

10. **Reduced Inequalities**

Reduce inequality within and among countries.

Meaning: Make the world fairer by helping reduce the gap between rich and poor and treating everyone with respect.

11. **Sustainable Cities and Communities**

Make cities and human settlements inclusive, safe, resilient, and sustainable.

Meaning: Make our towns and cities safe, clean, and friendly for everyone to live in.

12. **Responsible Consumption and Production**

Ensure sustainable consumption and production patterns.

Meaning: Use resources wisely by reducing waste, recycling more, and protecting nature.

13. **Climate Action**

Take urgent action to combat climate change and its impacts.

Meaning: Act now to reduce the effects of climate change and protect the planet.

14. **Life Below Water**

Conserve and sustainably use the oceans, seas, and marine resources.

Meaning: Keep our oceans, rivers, and sea life clean and healthy.

15. **Life on Land**

Protect, restore, and promote sustainable use of terrestrial ecosystems, forests, and biodiversity.

Meaning: Take care of forests, plants, and animals on land so they can survive and thrive.

16. **Peace, Justice, and Strong Institutions**

Promote peaceful and inclusive societies, provide access to justice for all, and build effective, accountable institutions.

Meaning: Make sure everyone is treated fairly and feels safe, with strong laws and good leadership.

17. **Partnerships for the Goals**

Strengthen the means of implementation and revitalise the global partnership for sustainable development.

Meaning: Work together with countries, communities, and people to achieve all these goals.

Activity 1.1 SDG Video Analysis

Objective: To define the SDGs using multimedia content.

Materials: Laptop, Projector, SDG introduction video.

Steps

1. Watch a short video introducing the 17 SDGs.
2. Scan this QR code or use the link below to watch the video



<https://youtu.be/7dzFbP2AgFo>

3. Discuss the meaning and relevance of each goal.

Questions

1. Which SDG stood out to you? Why?
2. How are the SDGs connected?

Activity 1.2 Engineering for Sustainability Brainstorm

Objective: To define SDGs and explore how engineering contributes to achieving them.

Materials Needed

- Chart paper or whiteboard
- Markers

Steps

1. Learn about the 17 Sustainable Development Goals (SDGs) by looking at their icons and understanding what each stands for.
2. In groups, discuss how different branches of engineering (like civil, electrical, environmental, or mechanical) can help achieve the SDGs.
3. Present your group's ideas to the class, explaining how engineering can support specific goals.

Questions

1. What is sustainable development?
2. How can engineers contribute to achieving the SDGs?
3. Which SDG do you think is most influenced by engineers?

Activity 1.3 Engineering Discipline-SDG Match

Objective: Match specific engineering disciplines with relevant SDGs.

Materials Needed

- Cards with engineering disciplines
- Cards with SDG goals and icons

Steps

1. Form groups of four students in each group.
2. Your teacher will randomly give each group a set of cards.
3. Work together to match each engineering discipline to the Sustainable Development Goals (SDGs) it supports the most.
4. As a class, discuss and review the matches to see how different types of engineering help achieve the SDGs.

Questions

1. Why did you match your engineering field with this SDG?
2. Can an engineering field support more than one SDG?

Activity 1.4 Design an SDG-Inspired Engineering Project

Objective: Conceptualise an engineering project that addresses a specific SDG.

Materials Needed

- Worksheets or poster boards
- Markers or pens

Steps

1. Divide into four smaller groups.
2. Each group will be assigned one Sustainable Development Goal (SDG).
3. Work together to brainstorm and design an engineering-based solution that helps achieve your assigned SDG (e.g., a water filtration system for clean water).
4. Present your group's design concept to the class and explain how it supports the SDG.

Questions

1. What problem does your project aim to solve?
2. What engineering principles are applied in your solution?
3. How does your solution help achieve your SDG?

Activity 1.5 SDG Gallery Walk with Engineering Focus

Objective: Explore various SDGs and how engineering solutions relate to them.

Materials Needed

- Posters with SDG summaries and related engineering examples
- Sticky notes for comments

Steps

1. Visit each station where a poster shows one SDG and a real-life engineering case study.
2. As you move around, read the information and write your thoughts, questions, or comments on sticky notes to post on the posters.
3. After the walkaround, participate in a class reflection to share what you learned and found interesting.

Questions

1. Which engineering solution did you find most inspiring?
2. Which SDG seems hardest to achieve with current engineering technologies?

Activity 1.6 Compare Engineering Challenges in SDGs

Objective: Compare how different engineering fields tackle similar SDG challenges.

Materials Needed

- Printed handouts or online resources
- Worksheet templates

Steps

1. Choose a global problem such as clean water, sustainable energy, or waste management.
2. Explain how different types of engineers (civil, mechanical, environmental, etc.) would approach solving that problem.
3. Share and discuss your ideas with the class to compare different engineering approaches.

Questions

1. How do different engineers approach the same problem?
2. Which approach is most sustainable or efficient?

EXPLAIN THE ROLE OF THE SDGs IN SOCIETAL DEVELOPMENT

The Role of the SDGs in Societal Development

The Sustainable Development Goals (SDGs) help countries, communities, and individuals work together to create a better and fairer world. The SDGs play a vital role in societal development by providing a global framework to improve the well-being of people, protect the planet, and ensure prosperity for all. They give us a clear plan for solving important problems and improving life for everyone.

Societal development means making improvements in how people live together in a society. This includes:

1. Better education and healthcare
2. Equal opportunities for everyone
3. Access to clean water, food, and energy
4. A safe and peaceful environment
5. A strong economy with good jobs

Here is how the SDGs help society

1. Ending Poverty and Reducing Inequality

The SDGs help us find ways to support people living in poverty and reduce unfair differences between the rich and the poor, so that everyone has equal chances in life. It helps build inclusive communities where no one is left behind.

The SDGs provide a framework to tackle poverty in all its forms, ensuring that even the poor have access to basic needs—like food, housing, and employment. By reducing inequality, they promote social cohesion, stability, and inclusive economic growth, which are essential for strong and just societies.

2. Promoting Education and Good Health

The SDGs remind us that every person deserves quality education and access to healthcare. These are important for helping people live better and contribute to society. SDGs focus on making sure everyone can go to school and get good healthcare. Educated and healthy people are more likely to get jobs and help develop society.

3. Protecting the Environment

The Sustainable Development Goals (SDGs) encourage us to use natural resources in a way that does not harm the planet. They also push us to protect ecosystems like forests, rivers, and oceans that support life on Earth. A big focus is fighting climate change by reducing pollution and using clean energy. By doing all these, we help create a healthier planet for ourselves and future generations.

4. Building Peaceful and Strong Communities

The SDGs promote good leadership and decision-making, also known as good governance. They encourage peace and fairness by making sure laws protect everyone

equally. They also focus on building strong cities and communities that can handle changes such as natural disasters and economic challenges. All of this helps to create safe and supportive places where people can live healthy and happy lives.

5. Encouraging Economic Growth

The SDGs aim to ensure everyone has access to decent work, where jobs are safe, fair, and pay enough to live on. They also encourage innovation, which means using new ideas and technology to solve problems in smarter ways. Another goal is to grow sustainable industries that protect the environment and treat workers well. By doing all this, the SDGs help build strong economies that benefit people without harming the planet.

6. Working Together Around the World

The SDGs highlight the importance of working together to solve big global problems. Countries are encouraged to support each other by sharing knowledge, resources, and ideas. Organisations and individuals also have a role to play by partnering on projects that make a difference. This increases the likelihood of a fairer, safer, and more sustainable world for everyone.

Activity 1.7 SDGs Explained in a Video

Objective: To explain the SDGs using multimedia content.

Materials: Laptop, Projector, SDG explained video.

Steps

1. Watch a short video on the SDGs explained.
2. Scan this QR code or use the link below to watch the video



<https://youtu.be/xubK4T9Nc8A>

3. Discuss the role of the SDGs.

Questions

1. What are the challenges facing the SDGs?
2. How are the SDGs reviewed?

Activity 1.8 Community Problem-Solving

Objective: To explore how SDGs provide solutions to community issues.

Materials Needed: Flip charts, markers.

Steps

1. Form small groups with your classmates.
2. As a group, choose a local community problem such as waste, water shortage, or unemployment.
3. Match your chosen issue to one or more relevant Sustainable Development Goals (SDGs).
4. Come up with engineering or social solutions that could help solve the problem in a way that supports the SDGs.

Questions

1. What SDG(s) address your community problem?
2. How can your solution improve societal well-being?

Activity 1.9 What to do if the SDGs Fail?

Objective: To think critically about the importance of the SDGs in societal progress.

Steps

1. Take a moment to think about what the world might be like if the Sustainable Development Goals (SDGs) are not achieved.
2. Talk about your thoughts with a partner and listen to their ideas too.
3. Share your ideas with the class and join the discussion.

Questions

1. What risks do we face if SDGs are ignored?
2. Which SDG is most critical to your country's development?

Activity 1.10 SDG Impact Poster

Objective: To visually explain how SDGs improve societies.

Materials Needed: Poster paper, markers, SDG icon printouts.

Steps

1. Get into small groups with your classmates.
2. Choose one Sustainable Development Goal (SDG) and create a poster showing how it helps improve society, the economy, and the environment.

3. Display your poster and explain your ideas to the class.

Questions

1. What real-life benefits does your SDG bring?
2. How does it relate to other SDGs?

DESCRIBE ENGINEERING SOLUTIONS FOR ATTAINING SPECIFIC SDGS

Engineering Solutions for Attaining Specific SDGs

Engineers play a vital role in addressing some of the world's biggest challenges by designing and building technologies, systems, and infrastructure that directly support the SDGs. Their work helps improve the quality of life, protect the environment, and create lasting solutions for both local and global problems. Below are some examples of engineering solutions that are directly linked to the SDGs.

1. SDG 6 – Clean Water and Sanitation
 - a. Designing affordable water filtration systems for rural areas.
 - b. Building efficient wastewater treatment plants to recycle water.
 - c. Developing rainwater harvesting and groundwater recharge systems to collect rainwater.
2. SDG 7 – Affordable and Clean Energy
 - a. Developing solar panels, wind turbines, and microgrids for renewable, off-grid energy solutions.
 - b. Creating energy-efficient appliances and smart grids for efficient energy usage and distribution.
3. SDG 9 – Industry, Innovation, and Infrastructure
 - a. Designing sustainable transportation networks like electric railways.
 - b. Building resilient bridges and buildings that can withstand natural disasters.
 - c. Using 3D printing and advanced materials for efficient, low-waste production.
 - d. Supporting sustainable manufacturing through automation and green technologies to improve production.
4. SDG 11 – Sustainable Cities and Communities
 - a. Engineering green buildings with low energy consumption.
 - b. Designing smart waste management systems to reduce landfill use.
5. SDG 13 – Climate Action

- a. Innovating carbon capture technologies to reduce industrial emissions.
 - b. Developing early warning systems for natural disasters like floods and hurricanes.
 - c. Developing renewable energy solutions and emissions monitoring systems to aid clean energy production.
6. SDG 3 – Good Health and Well-being
- a. Creating medical devices like low-cost ventilators and portable diagnostic tools.
 - b. Designing safe sanitation facilities to prevent the spread of diseases.
 - c. Development of telemedicine platforms and mobile health technologies to help in making access to healthcare reach everyone.
7. SDG 2 – Zero Hunger
- a. Building automated irrigation systems to help farmers grow more food sustainably.
 - b. Designing storage solutions that prevent food spoilage.
 - c. Using smart agriculture technologies like precision farming using drones and sensors to improve production.

Activity 1.11 Solar Power for All (SDG 7 – Affordable and Clean Energy)

Objective: To explore how solar technology can solve electricity problems in rural communities.

Materials Needed: Photos of solar panels, simple solar circuit kits or drawings, and case studies.

Steps

1. Learn about the issue of energy poverty and how it affects people living in rural areas without reliable electricity.
2. Explore how solar engineering can provide clean, renewable energy to communities that need it most.
3. Work on building or sketching a simple solar lighting system that could be used in a rural home or school.

Questions

1. Why is solar power a good solution for rural communities?
2. What challenges might an engineer face when implementing solar projects?

Activity 1.12 Clean Water Challenge (SDG 6 – Clean Water and Sanitation)

Objective: To demonstrate water filtration as a solution to unsafe drinking water.

Materials Needed: Sand, charcoal, gravel, bottles, and dirty water samples.

Steps

1. Learn and talk about the global problem of limited access to clean and safe drinking water.
2. In groups, design and build a simple water filter using materials you can easily find, like sand, gravel, and cloth.
3. Test your filters using dirty water, then compare your results with other groups to see which design worked best.

Questions

1. What materials worked best?
2. How do engineers improve large-scale water systems?

Activity 1.13 Design a Low-Cost House (SDG 1 – No Poverty)

Objective: To develop engineering ideas for affordable housing.

Materials Needed: Cardboard, glue, rulers, paper, and design templates.

Steps

1. Learn about the challenges of homelessness and poor housing in different communities.
2. Research affordable and sustainable building materials commonly used in low-cost housing projects.
3. In groups, design and build a small model house using your ideas and materials that reflect your research.

Questions

1. What features make a house affordable and sustainable?
2. How do engineers balance cost, safety, and comfort?

Activity 1.14 Smart Irrigation System (SDG 2 – Zero Hunger)

Objective: To describe engineering approaches to water-efficient farming.

Materials Needed: Diagrams of drip irrigation, water containers, and tubes.

Steps

1. Talk about the problems of water shortages and food insecurity, and how they affect communities.
2. Watch a demonstration or create a sketch of a simple drip irrigation system.
3. Explore how this system helps farmers use water efficiently and improve crop yields.

Questions

1. How does drip irrigation reduce water waste?
2. What other agricultural technologies solve hunger?

Activity 1.15 Mobile Health Clinic Design (SDG 3 – Good Health and Well-being)

Objective: To design a mobile clinic that provides healthcare in remote areas.

Materials Needed: Paper, coloured pencils, and internet access for research.

Steps

1. Discuss the challenges people in rural areas face when trying to access quality healthcare.
2. Design a mobile clinic that includes important features like solar panels for power, clean water tanks, and other essential facilities.
3. Share your group's design with the class and explain how each feature helps meet the healthcare needs of rural communities.

Questions

1. What makes a mobile clinic effective in isolated areas?
2. How can engineers adapt health tech to different environments?

Activity 1.16 Build a Digital Classroom (SDG 4 – Quality Education)

Objective: To show how technology-based solutions improve access to education.

Materials Needed: Sketch paper, internet access, sample devices.

Steps

1. Talk about educational barriers, like distance or lack of teachers.
2. Design a digital classroom setup (e.g., solar-powered tablets, internet hotspots).
3. Present and explain your system.

Questions

1. What problems does your solution solve?
2. How can engineers ensure devices work in low-resource settings?

Activity 1.17 Waste to Energy Model (SDG 11 – Sustainable Cities and Communities)

Objective: To understand how cities turn waste into useful energy.

Materials Needed: Diagrams of biogas plants, plastic bottles, and optional mini models.

Steps

1. Introduce the problem of urban waste.
2. Explore how engineers convert waste to biogas or electricity.
3. Create a model or diagram of a waste-to-energy system.

Questions

1. How does waste-to-energy improve city life?
2. What are the limitations of such solutions?

Activity 1.18 Ocean Cleanup Prototype (SDG 14 – Life Below Water)

Objective: To build a model that collects plastic from the oceans.

Materials Needed: Plastic bottles, nets, strings, glue, water container.

Steps

1. Talk about marine pollution and how plastic waste damages oceans and harms marine life.
2. Design and build a simple cleanup device using available materials.
3. Test your device in a small water container to see how well it collects or filters plastic waste.

4. Evaluate the results and discuss what worked well and what could be improved in your design.

Questions

1. What challenges arise in cleaning oceans?
2. How can engineers help prevent marine pollution?

DESIGNING AND DEVELOPING INNOVATIVE SOLUTIONS TOWARDS THE ATTAINMENT OF SDGS

To help achieve the Sustainable Development Goals (SDGs), you need to think like someone who finds innovative ways to solve real problems (i.e., an engineer, scientist, designer, or entrepreneur). Thus, develop new ideas, use technology wisely, and consider how your solutions affect people and the environment. Innovation encompasses more than creativity; it's also about understanding what communities need. When you combine creativity, technology, and care for the planet, you can help build a better future.

Key Approaches

1. Human-Centred Design

Solutions must be designed with the needs of people (especially vulnerable groups) in mind.

Example: Low-cost water filters for remote communities (supporting SDG 6: Clean Water).

2. Use of Emerging Technologies

Applying new tools like AI (Artificial Intelligence), IoT (Internet of Things), renewable energy systems, biotechnology, and advanced materials.

Example: Smart farming systems that use sensors to optimise crop yield (supporting SDG 2: Zero Hunger).

3. Sustainability Focus

Solutions must reduce resource consumption, minimise waste, and protect the environment.

Example: Biodegradable packaging materials to replace plastics (supporting SDG 12: Responsible Consumption).

4. Affordability and Scalability

Innovations must be low-cost and easily expandable to different regions or populations.

Example: Modular, solar-powered classrooms that can be installed quickly in underserved areas (supporting SDG 4: Quality Education).

5. Collaboration and Partnerships

Successful solutions often involve partnerships between governments, industries, communities, and researchers.

Example: Public-private partnerships to build clean energy plants (supporting SDG 7: Affordable and Clean Energy).

Examples of Innovative Solutions

Solution	Related SDG	Brief Description
Solar-powered water pumps	SDG 6	Provide clean water in drought-affected areas.
Vertical farming	SDG 2	Grow food using less land and water in urban areas.
E-health platforms	SDG 3	Deliver healthcare remotely to rural populations.
Electric public transport	SDG 11	Reduce pollution and improve urban mobility.
Carbon capture technology	SDG 13	Trap CO ₂ emissions from factories to fight climate change.

Activity 1.19 Design a Solar-Powered Lantern (SDG 7 – Affordable and Clean Energy)

Objective: To create a concept or prototype of a solar lantern for use in off-grid communities.

Materials Needed

- Mini solar panels (optional)
- LEDs, wires, switches, recycled plastic containers
- Cardboard, glue, tape, scissors
- Markers, paper for design sketches

Steps

1. Discuss energy access issues in rural areas (show real-life stories or videos).
2. Brainstorm basic lighting needs (e.g., for studying or working).
3. Sketch a design or build a prototype using available materials.
4. Ensure it includes a way to store solar energy (battery concept).
5. Present to the class with an explanation of how it works.

Questions

1. How is your design affordable and sustainable?
2. Who benefits most from your innovation and why?

Activity 1.20 Design a Rainwater Harvesting System (SDG 6 – Clean Water and Sanitation)

Objective: To design a system that collects and filters rainwater for household or school use.

Materials Needed

- Bottles, mesh, buckets, hosepipes, filters (sand/charcoal), paper, rulers
- Internet or books for research

Steps

1. Present water scarcity data from local or global regions.
2. Discuss how rainwater can be used safely.
3. In groups, design a harvesting and filtration system.
4. Build a small model or illustrate the system.
5. Explain how water is collected, filtered, and stored.

Questions

1. What challenges exist in your design?
2. How could it be implemented in real communities?

Activity 1.21 Smart Farming Model (SDG 2 – Zero Hunger)

Objective: To develop a model for increasing crop production using limited resources.

Materials Needed

- Soil, seeds, plastic trays
- Recycled water bottles, drip pipes or tubes
- Arduino kit (optional), or sensors (if available)

Steps

1. Introduce food insecurity and farming challenges (drought, pests).
2. Brainstorm simple, low-cost technologies to boost farming (e.g., drip irrigation).
3. Design or model a system that automates watering or maximises space.
4. Demonstrate or simulate how it works.

Questions

1. How does your solution improve productivity?
2. What makes it suitable for poor farmers?

Activity 1.22 Eco-Brick Furniture (SDG 12 – Responsible Consumption & Production)

Objective: To repurpose plastic waste into a functional item (e.g., bench or planter).

Materials Needed

- Empty plastic bottles, clean plastic wrappers
- Cardboard, scissors, glue
- Measuring tools

Steps

1. Discuss plastic waste issues in your local community.
2. Learn how to make an eco-brick by tightly stuffing plastic into bottles.
3. Decide on a furniture item to construct.
4. Assemble bricks into the design.
5. Share the benefits of the solution for waste management.

Questions

1. What environmental problem does this address?
2. How scalable is this solution for communities?

Activity 1.23 Inclusive School Design (SDG 4 & SDG 10 – Education and Reduced Inequality)

Objective: Design a school building or classroom layout that supports people with disabilities.

Materials Needed

- Cardboard, glue, paper, rulers, markers
- Access to inclusive education case studies

Steps

1. Discuss barriers people with disabilities face.
2. Research inclusive learning environments.
3. In groups, design a model of an inclusive school (with ramps, tactile signage, etc.).
4. Present the layout and accessibility features.

Questions

1. How does your design support inclusion?
2. What did you learn about equality in education?

Activity 1.24 Low-Cost Sanitation System (SDG 6) – With Systematic Investigation

Objective: Investigate rural sanitation challenges and design a low-cost, eco-friendly sanitation system using the systematic investigation process.

Materials Needed

- Recyclables: plastic bottles, tubes, small buckets, cardboard
- Sketch paper, glue, scissors, rulers, markers
- Scenario briefs or community profiles

Steps

1. Discuss the impact of poor sanitation or open defecation using a given village scenario.
2. Gather data on removing debris, types of toilets, material costs, water access, and waste management systems.
3. Compare sanitation system options based on cost, hygiene, environmental impact, and practicality.
4. In groups, sketch and build a model of a low-cost sanitation system using recyclable materials. Include hygiene and water-saving features.
5. Present your model, explain your design choices, and suggest possible improvements

Questions

1. What sanitation challenges does the community in your scenario face?
2. What types of toilets or sanitation systems did you research?
3. Which sanitation designs are most suitable based on cost, hygiene, and sustainability?
4. How did you ensure hygiene, water efficiency, and proper waste disposal in your model?
5. Which engineering discipline(s) would be involved in implementing your solution in a real-world context?

EXTENDED READING

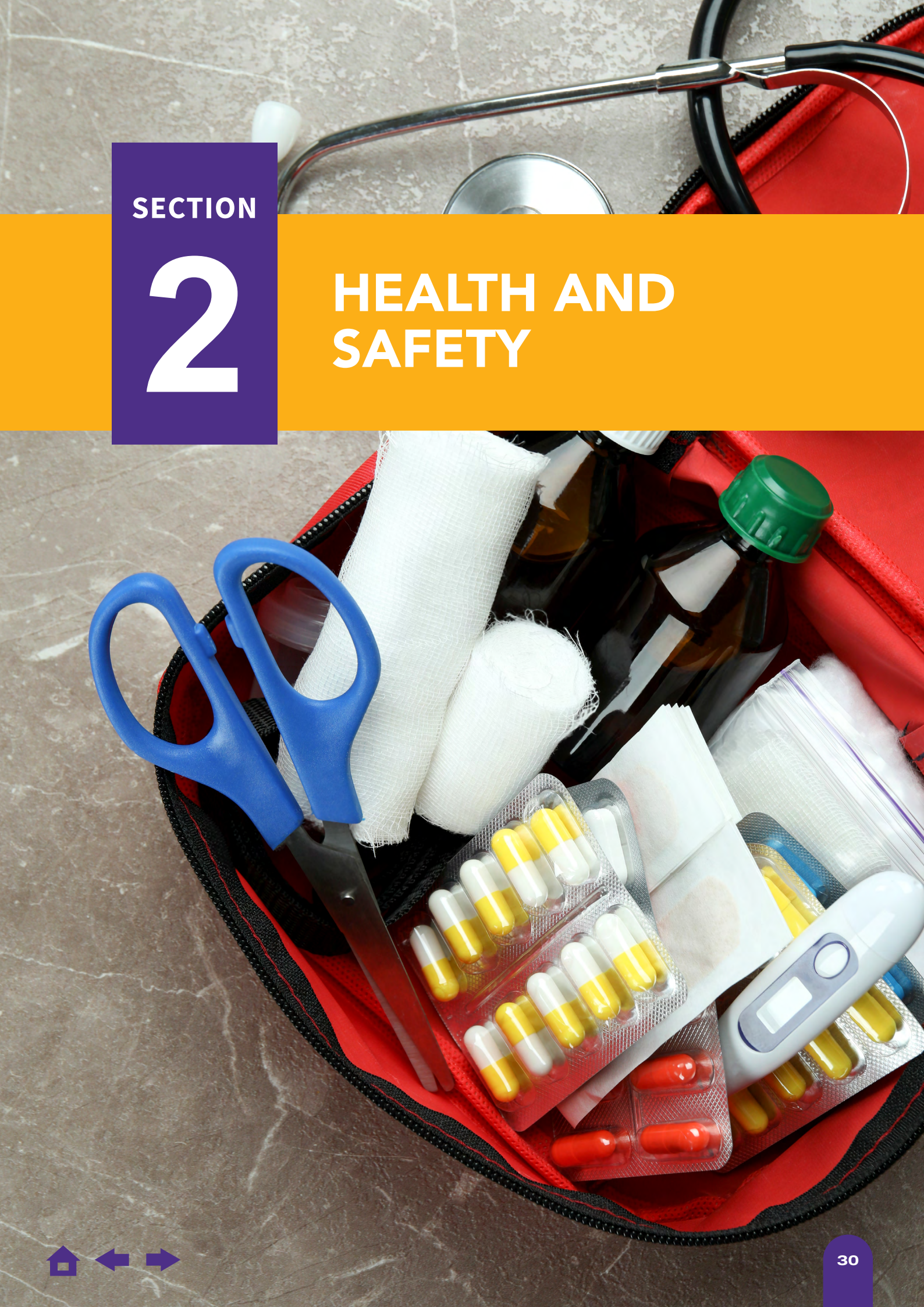
- Marschall, C., Crawford, E. O. (2021). *Worldwise Learning: A Teacher's Guide to Shaping a Just, Sustainable Future*. United States: Corwin Press.
- Dolan, A. M. (2024). *Teaching the Sustainable Development Goals to Young Citizens (10-16 Years): A Focus on Teaching Hope, Respect, Empathy and Advocacy in Schools*. United Kingdom: Taylor & Francis.
- *Education for Sustainable Development Goals: learning objectives*. (2017). France: UNESCO Publishing.

REVIEW QUESTIONS

1. How are the Sustainable Development Goals (SDGs) interconnected, and why is it important to consider them as a whole rather than individually?
2. Compare the focus of the SDGs with that of the earlier Millennium Development Goals (MDGs). What key differences can you identify?
3. In what ways do the SDGs promote both social equity and environmental protection simultaneously?
4. Evaluate the relevance of SDG 9 (Industry, Innovation, and Infrastructure) in transforming rural economies.
5. What role can youth play in advancing the Sustainable Development Goals, and why is their participation crucial?
6. Why is SDG 17 (Partnerships for the Goals) essential for the success of all other SDGs?
7. Analyse how achieving SDG 4 (Quality Education) can impact other goals such as SDG 5 (Gender Equality) and SDG 8 (Decent Work and Economic Growth).
8. What challenges might countries face in implementing the SDGs, and how can they overcome them?
9. If a country focuses only on economic growth without considering environmental sustainability, which SDGs might be negatively affected and how?
10. Critically assess whether the SDGs are achievable by 2030. What factors will determine their success?
11. How do the SDGs support long-term societal stability and peace, particularly in regions affected by poverty and conflict?
12. In what ways can investment in SDG 4 (Quality Education) influence the success of other goals and overall societal development?
13. Why is it important for governments to integrate the SDGs into national development plans to achieve societal progress?
14. Evaluate how achieving SDG 5 (Gender Equality) contributes to societal transformation.
15. What role do local communities play in achieving the SDGs and advancing societal development?
16. How can failure to address environmental SDGs (like SDG 13 – Climate Action) hinder societal development?
17. Analyse the impact of SDG 8 (Decent Work and Economic Growth) on reducing youth unemployment and boosting societal progress.
18. How do partnerships (SDG 17) between countries, organisations, and communities accelerate societal development?
19. Critically assess whether focusing only on economic growth, without social or environmental goals, can lead to sustainable societal development.

20. Explain how the SDGs create a framework for measuring societal progress beyond just economic indicators like GDP.
21. Design a low-cost water purification system for a flood-prone rural area to help achieve SDG 6 (Clean Water and Sanitation). What factors must you consider, and how would you test its effectiveness?
22. Propose an engineering-based solution to address energy poverty in remote communities aligned with SDG 7 (Affordable and Clean Energy). Justify your approach using environmental, economic, and social factors.
23. Critically evaluate a current engineering project (real or hypothetical) that aims to improve public transportation in line with SDG 11 (Sustainable Cities and Communities). What makes the solution innovative and sustainable?
24. As an engineer, design a multi-use agricultural system for a drought-prone region to contribute to SDG 2 (Zero Hunger) and SDG 13 (Climate Action). Describe the components and how they work together.
25. How would you apply the engineering design process to solve the challenge of poor waste management in your community (SDG 12 – Responsible Consumption and Production)? (DOK level 4)
26. Explain how a biomedical engineer could develop a cost-effective health device to support SDG 3 (Good Health and Well-being) in low-resource clinics. Include features, materials, and expected impact.
27. Develop a concept for a digital learning platform that helps rural students, supporting SDG 4 (Quality Education) and SDG 10 (Reduced Inequality). What engineering decisions influence its success?
28. How would you redesign urban housing in flood-prone slums to align with SDG 11 (Sustainable Cities) and SDG 1 (No Poverty)? Justify your engineering choices.
29. Propose an engineering innovation that supports SDG 5 (Gender Equality) by addressing a specific challenge faced by women or girls in developing countries. Explain its design and societal impact.
30. As part of an engineering team, you are asked to develop a national strategy for integrating green technology in public infrastructure to support SDG 13 (Climate Action). What should the strategy include and why?
31. You are tasked with developing an affordable solar-powered water purifier for a rural community. Describe your design, its key features, and how it aligns with SDG 6 and SDG 7.
32. Design a community-based solution to improve waste management in your local area. How would it contribute to SDG 11 (Sustainable Cities) and SDG 12 (Responsible Consumption and Production)?
33. Create a solution to improve access to education for girls in underserved areas. What engineering and social design aspects would you include, and how does this support SDG 4 and SDG 5?
34. Imagine your team is developing a low-tech irrigation system for drought-prone farming communities. How would you ensure the system is sustainable, cost-effective, and supports SDG 2 and SDG 13?

35. Propose an innovation that addresses youth unemployment through green technology. How does your solution support SDG 8 (Decent Work) and SDG 13 (Climate Action)?
36. Develop a solution that could reduce digital inequality in remote schools. What technologies would you use, and how would your innovation impact SDG 4 and SDG 10?
37. Design an innovation that provides clean cooking alternatives to households using firewood. What engineering elements would you include, and how would this help meet SDG 3 and SDG 7?
38. Imagine your school wants to become more sustainable. Propose an engineering solution that promotes environmental education and aligns with multiple SDGs.
39. How would you design a mobile health unit that can reach remote villages? Consider power, transport, and medical needs. How does this support SDG 3 and SDG 10?
40. You are part of a student team creating a startup that addresses an SDG through innovation. Choose one goal, explain your product or service, and describe how it creates a measurable impact.



SECTION

2

HEALTH AND SAFETY

HEALTH AND SAFETY IN ENGINEERING PRACTICE

INTRODUCTION

In this section, you will be exposed to the implementation of good housekeeping measures. Maintaining a clean, orderly, and secure environment at work, home, or in other settings is known as good housekeeping. Untidy, messy, filthy, or disorganised spaces are examples of poor housekeeping, which can have detrimental effects on individuals, companies, and the environment. You will understand that whether in a bustling production line, a quiet office or a rough construction site, good housekeeping enhances appearance, safety and efficiency. The section will also help you to identify essential materials for treating small wounds, avoiding infection, which are included in a typical first aid kit. You will also learn to demonstrate the ability to handle a crisis until expert assistance arrives. To ensure a prompt and efficient reaction to common incidents, you will understand the need to keep a first aid box, which usually contains bandages, gauze, antiseptic wipes, tweezers, pain medicines, gloves, cold packs, and a first aid manual.

KEY IDEAS

- **Basic First Aid for Workplace Accidents:** First aid provides immediate care for injuries like cuts, burns, electric shocks, and fainting. Key steps include ensuring safety, assessing the situation, and applying appropriate aid until help arrives.
- **Consequences of Poor Housekeeping:** Poor housekeeping can lead to slips, trips, fires, equipment damage, reduced efficiency, and health hazards.
- **Housekeeping Rules for Various Work Environments:** Different work settings (construction sites, manufacturing areas, offices) have specific housekeeping practices—like keeping walkways clear, proper tool storage, safe waste disposal, and maintaining sanitary conditions.
- **Importance of Good Housekeeping:** Good housekeeping ensures cleanliness, order, and safety in the workplace. It prevents accidents, improves productivity, and promotes a healthy working environment.
- **Workplace Safety and Welfare:** Ensuring worker safety involves identifying hazards, using protective equipment, following procedures, and providing access to clean facilities and medical care for overall well-being.

EXPLAIN THE NEED FOR GOOD HOUSEKEEPING

The Need for Good Housekeeping

Good housekeeping means keeping a workplace or environment clean, organised, and free from dangers. It is very important for safety and smooth work in homes, schools, hospitals, construction sites, factories, and offices.

1. Promotes Safety

- a. A clean and tidy space helps stop accidents like tripping, slipping, and falling.
- b. Removing clutter and storing flammable items safely helps prevent fires.
- c. Putting tools and materials in the right place helps avoid injuries.

2. Improves Efficiency

- a. When tools and equipment are neatly arranged and labelled, they are easier and faster to find.
- b. Work becomes smoother and better organised.

3. Enhances Health

- a. Cleaning often reduces dust, mould, and harmful germs that can make people sick.
- b. Proper waste disposal keeps the air fresh and the place hygienic.
- c. It creates a cleaner and healthier environment for everyone.

4. Boosts Morale and Professionalism

- a. A clean space makes people feel good and proud of where they work or learn.
- b. It shows the organisation cares about its people.
- c. Visitors and customers see the place as professional and responsible.

5. Protects Equipment and Materials

- a. Regular cleaning keeps tools and machines working well.
- b. Good storage prevents damage and saves money on repairs or replacements.

6. Supports Compliance

- a. Good housekeeping helps meet health, safety, and environmental rules.
- b. It prevents legal problems or penalties.

7. Prevents Fire Hazards

- a. Removing flammable materials and keeping exit routes clear helps stop fires.
- b. Storing chemicals and fuels properly makes them safer to use.

Activity 2.1 Walk-Through Inspection

Objective: To observe and identify good and poor housekeeping practices.

Materials Needed: Notebooks, pens, checklist template.

Steps

1. Join a small group.
2. Provide a checklist of common housekeeping items (e.g., clutter, spills, storage).
3. Walk through the school's classroom or workshop areas.
4. Note good and bad practices.
5. Check for emergency readiness (e.g., visible exits, access to first aid)
6. Create a **basic Workplace Safety Plan** that includes;
 - a. Summary of identified hazards
 - b. Recommendations for improving housekeeping
 - c. Emergency response protocols (what to do, who to contact, where to go)
7. Present your plan to the class via a short presentation or visual poster.

Questions

1. What types of hazards did you observe?
2. How can those be avoided?
3. Which good housekeeping practices did you see, and why are they effective?
4. How can poor housekeeping lead to more serious safety issues?
5. What should a workplace safety plan/emergency response plan include?
6. How can regular inspections prevent accidents or injuries?

Activity 2.2 Spot the Hazard (Photo Analysis)

Objective: To identify poor housekeeping in images.

Materials Needed: Printed or digital photos showing unsafe or untidy workspaces.

Steps

1. You will be shown images of messy and clean workspaces.
2. Identify and circle hazards in the messy images.
3. Discuss what could be improved and why.

Questions

1. What are the dangers of poor housekeeping shown in the photos?
2. How can these situations be corrected?
3. How do these hazards affect safety and productivity?

Activity 2.3 Clean-Up Challenge

Objective: To experience the benefits of a clean and organised environment.

Materials Needed: Cleaning supplies, storage containers, labels.

Steps

1. Join a small group.
2. Your group will be assigned to a messy area or corner of the classroom/lab.
3. In your group, organise and clean the area.
4. Evaluate each cleaned space based on cleanliness, order, and safety.

Questions

1. How did the area look before and after cleaning?
2. How does good housekeeping make the space safer?
3. What did you learn about teamwork and cleanliness?

Activity 2.4 Good vs Poor Housekeeping Role-Play

Objective: To demonstrate the impact of good and poor housekeeping on safety.

Materials Needed: Simple props (books, cables, tools).

Steps

1. Join a group.
2. In your group, act out a short scene of a workspace with poor housekeeping.
3. Then act out the improved version with good housekeeping.
4. Others will observe you and give feedback.

Questions

1. What changes did you see between the two versions?
2. How did poor housekeeping affect the work or safety in the role-play?
3. Why is attention to detail important?

Activity 2.5 Organising Tools and Equipment

Objective: To practice safe storage of tools and materials.

Materials Needed: Tools, storage shelves, bins, labels.

Steps

1. You will be shown a disorganised tool area.
2. Discuss safety issues present.

3. Organise tools by type and label storage spaces.

Questions

1. How does organised storage reduce risk?
2. What problems occur when tools are left out?
3. How does good storage affect efficiency?

Activity 2.6 Housekeeping in Real Life

Objective: To reflect on housekeeping practices at home, school, or work.

Steps

1. Think about a time you encountered poor housekeeping.
2. Pair with a classmate to share experiences.
3. Discuss as a class how the issues could have been avoided.

Questions

1. What happened because of poor housekeeping?
2. How was the problem solved (or not)?
3. What lessons can we apply at school or in the workplace?

CONSEQUENCES OF POOR HOUSEKEEPING

Poor housekeeping means a place is messy, dirty, cluttered, or not well organised. This can cause serious problems for people, workplaces, and the environment.

Here are some of the main problems it can cause.

1. Increased Accidents and Injuries

- a. Cluttered walkways, spilt liquids, and misplaced tools cause trips, slips, falls, and collisions.
- b. Poorly stored materials can fall and injure people.

2. Fire Hazards: Accumulated waste, flammable materials, and blocked fire exits increase the risk of fires and make emergency evacuation more difficult.

3. Health Risks

- a. Dust, mould, pests, and chemical spills can cause respiratory issues, allergies, infections, and other health problems.
- b. Poor sanitation can spread diseases.

4. **Low Productivity and Efficiency**

- a. Time is wasted searching for misplaced tools, documents, or materials.
- b. Workers become frustrated and work more slowly in a disorganised environment.

5. **Damage to Equipment and Property**

- a. Dust, dirt, and spills can damage machines, tools, and electronic equipment.
- b. Poor maintenance shortens the lifespan of valuable assets.

6. **Negative Image and Reputation**

- a. Visitors, customers, or inspectors may view an untidy place as unsafe and unprofessional.
- b. This can hurt business credibility and future opportunities.

7. **Legal and Financial Consequences**

- a. Poor housekeeping can lead to violations of safety laws and standards.
- b. Organisations may face fines, lawsuits, or shutdowns after inspections or accidents.

Poor housekeeping can make a place unsafe, unhealthy, and disorganised. It can cause accidents and injuries, lead to wasted time and money, make people sick, damage tools, machines, or materials, and give the place a bad reputation.

Keeping things clean and in order helps everyone stay safe and work better.

Activity 2.7 Hazard Hunt

Objective: To identify safety hazards caused by poor housekeeping.

Materials Needed: Observation checklist, pens, classroom/workshop with messy areas.

Steps

1. Join a small group.
2. Each group will be provided with a hazard checklist.
3. Visit an area of the school (lab, storeroom, classroom).
4. Groups identify and record hazards related to poor housekeeping.
5. Groups present findings to the class in 5 minutes.

Questions

1. What hazards did you identify?
2. How did poor housekeeping contribute to those hazards?
3. What incidents could result from these hazards?

Activity 2.8 Accident Scene Re-enactment

Objective: To demonstrate how poor housekeeping can lead to accidents.

Materials Needed: Simple props (e.g., books, cords, spilt water), accident scene script.

Steps

1. You will be assigned a role to enact (victim, observer, responder).
2. A scenario will be set up showing poor housekeeping (e.g., a trip over clutter).
3. Act out the scenario.
4. Discuss with the class what caused the accident and how it could have been avoided.

Questions

1. What part of the scene showed poor housekeeping?
2. What could have been done differently?
3. What are the short- and long-term consequences of such accidents?

Activity 2.9 Cause and Effect Chart

Objective: To understand the relationship between poor housekeeping and its consequences.

Materials Needed: Chart paper, markers.

Steps

1. Join a small group.
2. Groups create a chart with two columns: “Poor Housekeeping Practice” and “Possible Consequences”.
3. Fill in examples (e.g., “Wet floor” → “Slip and fall”).
4. Share charts and discuss.

Questions

1. Which consequences surprised you?
2. How are people affected physically and emotionally?
3. How can such situations be prevented?

Activity 2.10 Case Study Analysis

Objective: To analyse real-life incidents caused by poor housekeeping.

Materials Needed: Printed or digital case studies (can be created or sourced), pens.

Steps

1. Join a small group.
2. Each group will be provided with a different case study of a workplace or school accident.
3. Read and analyse what went wrong.
4. Discuss causes, effects, and lessons learned.

Questions

1. What poor housekeeping practice led to the incident?
2. What were the results of the incident?
3. What should have been done differently?

Activity 2.11 “Before and After” Comparison

Objective: To visually compare the outcomes of poor and good housekeeping.

Materials Needed: Sets of “before and after” images, projector/printouts.

Steps

1. You will be shown side-by-side images of messy vs. tidy environments.
2. In groups, discuss risks and consequences in the “before” images.
3. Identify improvements in the “after” images.

Questions

1. What risks are visible in the messy image?
2. How does the clean and tidy version reduce danger?
3. What can this teach us about daily maintenance?

Activity 2.12 Group Debate – “Poor Housekeeping Causes More Harm Than Good”

Objective: To critically evaluate the impact of poor housekeeping.

Materials Needed: Debate format guide, timer.

Steps

1. Split into two groups: one supports the motion, the other opposes.
2. Each group prepares arguments.
3. Hold the debate in class.
4. Each group is given a maximum of ten (10) minutes to present its case.

Questions (post-debate)

1. Which arguments were most convincing?
2. Do you agree that poor housekeeping has serious consequences?
3. How can awareness of consequences lead to better habits?

Activity 2.13 Brainstorming Session – “What If We Ignore It?”

Objective: To think critically about ignoring poor housekeeping.

Materials Needed: Whiteboard, markers, sticky notes.

Steps

1. “What happens if we ignore poor housekeeping?” is written up on the board.
2. Write possible outcomes on sticky notes.
3. Stick notes on the board and group similar ideas.
4. Discuss each cluster of ideas.

Questions

1. Which consequences are immediate, and which are long-term?
2. How does neglect affect safety, health, and work?
3. What is the cost of doing nothing?

HOUSEKEEPING RULES AT CONSTRUCTION SITES, MANUFACTURING/PRODUCTION AREAS AND OFFICES

Housekeeping Rules at Construction Sites, Manufacturing/Production Areas, and Offices

1. Construction Sites

- a. Keep pathways and access routes clear by removing debris, tools, and materials from walkways, and ensuring emergency exits are accessible.
- b. Dispose of waste promptly by using proper bins for general, hazardous, or recyclable waste, and cleaning up after cutting, drilling, or mixing materials.
- c. Secure tools and equipment by storing hand tools in toolboxes and locking up or tying down loose items, especially at heights to prevent tools and materials from falling.
- d. Control dust and mud by using water or dust suppression methods and cleaning mud from footwear and vehicles to prevent slippery surfaces.
- e. Organise materials and supplies by stacking materials safely and labelling where needed and avoiding overloading storage areas.
- f. Avoid fire hazards by keeping flammable materials away from ignition sources and storing chemicals in clearly labelled approved containers.
- g. Mark and cover hazards by barricading open pits or exposed wires and using signs to warn of wet floors, holes, or dangerous zones.
- h. Properly store tools and materials by keeping tools in toolboxes or designated storage areas and stacking materials safely to prevent collapse.
- i. Maintain proper lighting and signage by ensuring work areas are well-lit and hazard signs are visible.
- j. Avoid blocking emergency exits and fire equipment by keeping fire extinguishers, alarms, and exits accessible.

2. Manufacturing/Production Areas

- a. Keep floors clean and free of debris by regularly sweeping or mopping floors and cleaning spills promptly.
- b. Organise tools and equipment by returning tools to proper storage after use and labelling shelves and storage spaces.
- c. Dispose of scrap and waste materials properly by using appropriate containers for metal, plastic, chemical, or hazardous waste.
- d. Keep machines and equipment clean by removing buildup of dust or grease; perform routine cleaning.
- e. Maintain clear aisles and emergency exits by not storing items in passageways or block access points.

- f. Ensure proper storage of materials by stacking safely and respecting weight limits.
- g. Keep ventilation and lighting systems unobstructed by ensuring good airflow and visibility.
- h. Report damaged tools or safety hazards by encouraging quick action to fix any unsafe conditions.

3. Offices

- a. Keep desks and workspaces tidy by avoiding clutter and organising files, stationery, and personal items.
- b. Dispose of waste and recycling properly by using appropriate bins and empty them regularly.
- c. Manage cables and cords by securing and organising cords to prevent tripping.
- d. Keep walkways and exits clear by avoiding placing bags, boxes, or chairs in pathways.
- e. Clean up spills in common areas immediately by preventing slips in kitchens, lobbies, or restrooms.
- f. Store office supplies neatly by using shelves, cabinets, and drawers effectively.
- g. Maintain shared spaces by cleaning up after using meeting rooms or break areas.
- h. Report maintenance issues or hazards by alerting appropriate personnel about leaks, broken items, or electrical problems.

Good housekeeping helps make every workplace safer, more efficient, and more organised, whether it is a noisy construction site, a busy factory, or a quiet office.

Activity 2.14 The need for good housekeeping at construction sites video

Objective: The need for good housekeeping at construction sites using multimedia content.

Materials: Laptop, Projector, Good housekeeping introduction video.

Steps

1. Watch a short video on good housekeeping.
2. Scan this QR code or use the link below to watch the video



<https://youtu.be/3Hb1T6OX00o?si=UHigxSb4NGIUdCah>

3. Discuss the need for good housekeeping at construction sites.

Questions

1. What are the causes of poor housekeeping at a construction site?
2. What are the housekeeping rules for a construction site?
3. Why is proper housekeeping important at a construction site?

Activity 2.15 Compare and Contrast Chart

Objective: To compare housekeeping rules across different work environments.

Materials Needed: Chart paper, markers or printed templates.

Steps

1. Join a small group.
2. Each group will be assigned two environments (e.g., construction vs. manufacturing).
3. Create a chart showing similarities and differences in housekeeping rules.
4. Present and discuss findings with the class.

Questions

1. What rules are common across all environments?
2. Why do some rules differ by environment?
3. How does the nature of work affect housekeeping needs?

Activity 2.16 Visual Rule Posters

Objective: To design informative posters that outline housekeeping rules for specific workplaces.

Materials Needed: Poster boards, markers, glue, images (printed or from magazines).

Steps

1. Join a small group.
2. Each group will be assigned one environment: construction site, production area, or office.
3. Groups design a poster that outlines at least 5 key housekeeping rules for that space.
4. Display the posters in the classroom.

Questions

1. What visuals did you use to communicate your message?
2. Why are these rules especially important in your assigned environment?
3. How can posters promote workplace safety?

Activity 2.17 Scenario Role-Play

Objective: To demonstrate the importance of following housekeeping rules through acting.

Materials Needed: Script cards or student-created scenarios, basic props.

Steps

1. Join a small group.
2. Groups create short role-plays showing what happens when housekeeping rules are followed or ignored.
3. Include consequences such as injuries or hazards.
4. Perform for the class and discuss.

Questions

1. Which rule was broken or followed?
2. What were the results of the actions in the role-play?
3. How can this situation be avoided in real life?

Activity 2.18 Housekeeping Walkthrough

Objective: To observe and record housekeeping practices in different school areas.

Materials Needed: Housekeeping checklist, pens, observation sheets.

Steps

1. Join a small group.
2. Your group will be assigned to inspect areas of the school (e.g., workshop, lab, office).
3. Use the checklist to assess housekeeping.
4. Identify which environment (construction/production/office) it most closely resembles.
5. Share findings and suggest improvements.

Questions

1. What good housekeeping practices did you observe?
2. What areas need improvement?
3. How can we apply workplace rules to our school?

Activity 2.19 Housekeeping Rule Match-Up

Objective: To match specific rules to the correct work environment.

Materials Needed: Printed rule cards, labels for “Construction”, “Production”, and “Office”.

Steps

1. Create cards with various housekeeping rules.
2. Match each card to the environment it best applies to.
3. Discuss reasoning as a group.

Questions

1. Why does this rule apply more to one environment than the other?
2. Which rules apply to all environments?
3. What might happen if this rule is ignored?

Activity 2.20 “Design Your Own Workplace”

Objective: To apply housekeeping rules by designing a clean and safe work environment.

Materials Needed: Drawing paper, coloured pens/pencils, rulers.

Steps

1. Draw a layout of a construction site, production area, or office.
2. Include safety signs, storage areas, clear walkways, and waste bins.
3. Label areas with appropriate housekeeping rules.

Questions

1. What housekeeping rules did you include and why?
2. How does your design promote safety and order?
3. How would your design help workers stay organised?

Activity 2.21 Group Presentation – “Why Housekeeping Matters”

Objective: To explain the purpose and impact of housekeeping rules in each setting.

Materials Needed: Presentation materials (PowerPoint, chart paper, markers).

Steps

1. Join a small group.
2. Each group will be assigned one environment.
3. Groups prepare a short presentation explaining key housekeeping rules and their benefits.

4. Present to the class in 5 minutes.

Questions (After each presentation)

1. What rule stood out to you and why?
2. How do these rules improve health and safety?
3. What would happen if these rules were ignored?

Activity 2.22 Hazard Identification Challenge

Objective: To identify what happens when housekeeping rules are ignored.

Materials Needed: Photos or illustrations showing unsafe conditions, pens.

Steps

1. View images of poor housekeeping in different environments.
2. Write down which housekeeping rule was broken.
3. Suggest a corrective action.

Questions

1. What rule was ignored in this image?
2. What risk does it pose?
3. What could be done to fix it?

ADMINISTERING FIRST AID TO VICTIMS OF COMMON WORKPLACE ACCIDENTS

A first aid kit has important items that help treat small injuries, stop infection, and give support until medical help arrives.

It usually contains things like bandages, gauze, antiseptic wipes, tweezers, painkillers, gloves, cold packs, and a first aid guide. These tools help you respond quickly and safely to common accidents.

Table 2.1 shows some of the common items found in a first aid kit and what they are used for.

Table 2.1: Common items found in a first aid kit and what they are used for

S/N	Item	Use
1.	Adhesive bandages (plasters)	Cover small cuts, blisters, or abrasions to prevent infection.
2.	Sterile gauze pads	Absorb blood and exudate from larger wounds; used under bandages.

3.	Adhesive tape	Secure gauze pads or dressings in place.
4.	Antiseptic wipes	Clean wounds or hands to kill germs before dressing a wound.
5.	Antibiotic ointment	Prevent infection in minor cuts and scrapes.
6.	Hydrogen peroxide	Disinfect wounds (use with caution, can damage tissue).
7.	Tweezers	Remove splinters, debris, or stingers from the skin.
8.	Scissors	Cut gauze, tape, or clothing around a wound.
9.	Instant cold pack	Reduce swelling, pain, or bruising from sprains or insect bites.
10.	Elastic bandage (ACE bandage)	Support sprains and strains; reduce swelling.
11.	Thermometer	Measure body temperature to detect fever.
12.	Disposable gloves	Protect the wearer and patient from infection during treatment.
13.	CPR face shield/mask	Provide safe mouth-to-mouth resuscitation.
14.	Burn cream or gel	Soothe minor burns and prevent infection.
15.	Eye wash or saline solution	Rinse out foreign objects or chemicals from the eyes.
16.	Safety pins	Secure bandages or create slings.
17.	Triangular bandage	Create slings or support injured limbs.
18.	Pain relievers (e.g. paracetamol, ibuprofen)	Relieve pain, inflammation, or fever.
19.	Alcohol pads	Disinfect skin or instruments.
20.	First aid manual	Provide instructions on basic emergency care.

First aid is the immediate care given to an injured or ill person before professional medical help arrives.

How to Handle Common Workplace Accidents

Cuts and Bleeding

1. Wash your hands and wear disposable gloves.
2. Apply gentle pressure using a clean cloth or gauze to stop bleeding.
3. Elevate the injured area if possible.
4. Clean the wound with clean water (do not use alcohol or hydrogen peroxide).

5. Apply a sterile dressing or bandage.
6. If bleeding doesn't stop or the cut is deep, seek medical help.

Burns (Thermal, Chemical, or Electrical)

Thermal Burns

- a. Remove the person from the source of heat.
- b. Cool the burn with cool (not cold) running water for at least 10 minutes.
- c. Cover the area with a clean, non-stick dressing or cloth.
- d. Do not apply ice, ointment, or butter.
- e. For severe burns (blisters, charred skin), call emergency services.

For Chemical Burns

- a. Flush the area with large amounts of water for 15–20 minutes.
- b. Remove any contaminated clothing.
- c. Avoid touching the chemical with bare hands.
- d. Seek medical attention immediately.

Fractures (Broken Bones)

- a. **Do not move** the injured area unless necessary.
- b. **Keep the person still** and calm.
- c. **Support the limb** using a splint or improvised item (e.g., rolled newspaper, stick) without changing its position.
- d. Apply a **cold compress or ice** to reduce swelling (wrap ice in a cloth).
- e. **Elevate** the limb if it does not cause more pain and there's no suspicion of spinal injury.
- f. **Call for emergency medical help.**
- g. **Monitor for shock** (pale, cold skin, rapid breathing).

Sprains and Strains

Use the RICE method

- a. **Rest** the injured area (avoid movement).
- b. **Ice** the area for 15–20 minutes every 2–3 hours (use a wrapped cold pack).
- c. **Compress** with an elastic bandage to reduce swelling (not too tight).
- d. **Elevate** the injured limb above heart level if possible.
- e. Seek medical advice if severe.

Eye Injuries (Chemical Splashes or Debris)

Chemical Splashes

- a. Hold the eyelids open.
- b. Rinse the eye with clean, lukewarm water or saline for at least 15–20 minutes.

- c. Tilt the head so the affected eye is downward to prevent contamination of the other eye.
- d. Do not allow the person to rub the eye.
- e. Seek immediate medical attention.

Foreign Objects (Dust, Debris)

- a. Ask the person not to rub the eye.
- b. Gently rinse the eye with clean water or saline.
- c. If the object is not flushed out or remains stuck, cover the eye loosely with a sterile cloth and get medical help.
- d. Do not try to remove embedded objects.

Choking

For a Conscious Adult (Heimlich Manoeuvre)

- a. Ask: “Are you choking?” If the person can’t respond verbally, act quickly.
- b. Stand behind the victim and wrap your arms around the waist.
- c. Make a fist with one hand and place it just above the navel.
- d. Grasp the fist with the other hand.
- e. Deliver quick, inward and upward thrusts to expel the object.
- f. Continue until the object is expelled or the person becomes unconscious.

If the Person Becomes Unconscious

- a. Lower them gently to the floor.
- b. Call for emergency medical help.
- c. Start CPR if trained.
- d. Check the mouth between compressions and remove visible obstructions carefully.

Note: Never perform abdominal thrusts on a conscious person who is coughing forcefully or can speak; encourage them to keep coughing.

Electric Shock

1. Switch off the power source immediately if safe to do so.
2. Do **not** touch the victim until the power source is turned off.
3. Check for breathing and pulse.
4. If not breathing, begin CPR if trained.
5. Cover burns with sterile gauze if present.
6. Call for emergency help immediately.

Important Reminders

1. Stay calm and reassure the victim.

2. Always check the scene for danger before helping.
3. Use **PPE** (Personal Protective Equipment) like gloves when available.
4. Call for **professional medical help** if the injury is beyond basic first aid.
5. Keep a **well-stocked first aid kit** in all work areas.



Figure 2.1: Picture of items found in a First Aid kit

Activity 2.23 Watch this video on basic first aid training

Objective: Basic first aid training using multimedia content.

Materials: Laptop, Projector, basic first aid introduction video.

Steps

1. Watch a short video on basic first aid training.
2. Scan this QR code or use the link below to watch the video



<https://youtu.be/5OKFljZ2GQE>

3. Discuss the basic first aid training from the video.

Questions

1. What should you do first before helping someone who is injured?
2. How can you check if a person is responsive or unconscious?
3. Why is it important to wear gloves or other protection when giving first aid?
4. What are the basic steps for treating a bleeding wound shown in the video?
5. Which first aid skill from the video do you think is most useful in your school or workshop, and why?

Activity 2.24 Treating Cuts and Bleeding

Objective: To practice managing minor and severe bleeding.

Materials Needed: Gauze pads, gloves, red-coloured water (simulated blood), bandages.

Steps

1. Demonstrate how to put on gloves and apply direct pressure to a wound.
2. Practice with a partner using red-coloured water on a bandage.
3. Demonstrate elevation and secure dressing techniques.

Questions

1. What's the first thing to do when someone is bleeding?
2. Why is applying pressure important?
3. When should you seek emergency help?

Activity 2.25 First Aid for Burns

Objective: To apply correct first aid for thermal burns.

Materials Needed: Bowls of cool water, cloths, burn dressing materials, posters of burn degrees.

Steps

1. Explain types of burns and their severity.
2. Simulate cooling a burn using cloths soaked in cool water.
3. Practice covering with non-stick bandages.

Questions

1. Why shouldn't you use ice or butter on burns?
2. When is a burn considered severe?
3. How does cool water help?

Activity 2.26 Managing Fractures

Objective: To learn how to immobilise a limb with a suspected fracture.

Materials Needed: Splints (wood/plastic), bandages, rolled towels, scenario cards.

Steps

1. Demonstrate how to immobilise an arm or leg using a splint.
2. Work in pairs to practice on each other (mock situations).
3. Review signs of shock and care during transport.

Questions

1. What are the signs of a fracture?
2. Why should you not move the limb?
3. What is the goal of using a splint?

Activity 2.27 R.I.C.E. for Sprains and Strains

Objective: To treat sprains using Rest, Ice, Compress, Elevate (R.I.C.E.).

Materials Needed: Elastic bandages, cold packs, towels, and pillows.

Steps

1. Demonstrate each R.I.C.E. step.
2. Work in small groups to apply R.I.C.E. to a mock sprain.
3. Discuss differences between sprains and fractures.

Questions

1. What does R.I.C.E. stand for?
2. When should a sprain be seen by a doctor?
3. How does compression help?

Activity 2.28 Treating Eye Injuries (Chemical and Debris)

Objective: To practice flushing the eye for chemical splashes or debris.

Materials Needed: Eye wash bottle, eye models or partner, and goggles.

Steps

1. Demonstrate proper technique for eye irrigation (tilt, flush, duration).
2. Simulate the procedure using water and partners or models.
3. Discuss how to handle embedded objects.

Questions

1. How long should you flush the eye?

2. Why should you avoid touching the eye?
3. What's the difference between treating a splash and a foreign object?

Activity 2.29 Choking Response Practice

Objective: To demonstrate abdominal thrusts (Heimlich manoeuvre).

Materials Needed: Choking vest (if available), soft cushion, scenario cards.

Steps

1. Discuss signs of choking.
2. Pair up and simulate abdominal thrusts safely (no real pressure).
3. Practice what to do if the person becomes unconscious.

Questions

1. What signs show someone is choking?
2. When should you call emergency services?
3. What if the person becomes unconscious?

Activity 2.30 First Aid for Electrical Shock

Objective: To learn the first response to electrical shock incidents.

Materials Needed: Insulating items (wood stick, gloves), mock wires, scenario cards.

Steps

1. Simulate a scene where a victim is in contact with electricity.
2. Demonstrate safe steps: don't touch, shut power, call for help.
3. Practice checking responsiveness and starting CPR if trained.

Questions

1. What's the first step in treating an electrical shock victim?
2. Why must you not touch the person?
3. What signs of injury can occur after shock?

Activity 2.31 First Aid Relay Game

Objective: To apply first aid knowledge in a fast-paced challenge.

Materials Needed: Scenario cards, props, bandages, splints, and towels.

Steps

1. Divide into teams.

2. Visit stations set up for each injury type (cut, burn, fracture, etc.).
3. Teams rotate, responding to each injury using proper first aid.

Questions (at each station)

1. What's the injury?
2. What's the first step?
3. What could go wrong if done incorrectly?

Activity 2.32 Create a First Aid Guidebook

Objective: To reinforce knowledge by creating a personal reference tool.

Materials Needed: Booklets or folders, pens, markers, and printed templates.

Steps

1. Visit a section for each type of injury.
2. Add steps, dos and don'ts, and signs of severity.
3. Use as a revision or class resource.

Questions

1. What key steps must be remembered for each injury?
2. Which injury is most urgent?
3. How does this guide help you stay prepared?

Activity 2.33 Emergency Role-Play and Review

Objective: To simulate realistic workplace emergencies and apply first aid.

Materials Needed: Props (gloves, fake blood, safety cones), scenario scripts.

Steps

1. Join a small group.
2. Groups perform short scenes (e.g., worker burns hand on machine).
3. Others observe and provide feedback on first aid response.
4. Discuss what was done well and what could be improved.

Questions

1. Was the response realistic and safe?
2. What did you learn from the scenario?
3. How can communication affect first aid success?

Activity 2.34 Safe Engineering Workspace Simulation

Objective: You will explore workplace safety by identifying poor housekeeping, applying first aid, explaining tool safety, and performing a basic risk assessment.

Materials Needed

- Scenario cards (construction, factory, office)
- First aid kit (demo)
- PPE samples
- Risk assessment template
- Images of safe/unsafe workspaces
- Markers and paper

Steps

1. **Intro Discussion** (5 mins): Discuss the meaning and importance of good housekeeping.
2. **Group Task** (20 mins)
 - a. Analyse the assigned workspace scenario.
 - b. Identify housekeeping issues and safety risks.
 - c. Demonstrate first aid for one likely accident.
 - d. List tool/machine safety protocols.
 - e. Complete a simple risk assessment.
3. **Present & Reflect** (10 mins): Share group findings and discuss lessons learned.

Questions

1. Why is good housekeeping important?
2. What accidents can happen in your scenario?
3. What first aid did you apply and why?
4. What safety rules should be followed for the tools/machines?
5. How did your group assess and reduce risk?

EXTENDED READING

- Lingard, H., Rowlinson, S. M. (2005). Occupational health and safety in construction project management. United Kingdom: Spon Press.
- Advances in Safety Management and Human Factors: Proceedings of the AHFE 2017 International Conference on Safety Management and Human Factors, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA. (2017). Switzerland: Springer International Publishing.
- Occupational Health and Safety: A Multi-Regional Perspective. (2018). United Kingdom: IntechOpen.

REVIEW QUESTIONS

1. Why is good housekeeping important in a workplace environment?
2. How does good housekeeping reduce the risk of slips and falls?
3. In what ways does poor housekeeping affect workplace productivity?
4. How does good housekeeping promote safety in construction sites?
5. What role does good housekeeping play in emergencies?
6. How can good housekeeping help prevent fire hazards?
7. Why is it necessary to dispose of waste materials promptly at the workplace?
8. Explain how good housekeeping can improve employee morale.
9. Why is regular inspection part of good housekeeping practice?
10. How do labelling and organising tools contribute to good housekeeping?
11. *In a school workshop, tools are scattered on the floor, and workbenches are untidy. One student tripped over a hammer and twisted their ankle.* What does this scenario show about the consequences of poor housekeeping?
12. *A worker in a printing shop spills ink but doesn't clean it up. Later, another worker slips and hits their head.* What caused the accident, and how could it have been prevented?
13. *At a construction site, empty cement bags and debris are left along walkways. A site inspector issues a safety violation notice.* Why was the construction site penalised, and what lesson does this teach?
14. *An office has electrical cords running across the floor. An employee stumbles and drops a laptop.* What is the consequence of poor cable management in the workplace?
15. *A laboratory fails to label and store chemicals properly. A student accidentally mixes two incompatible substances, causing a minor explosion.* How is poor housekeeping linked to this incident?
16. *In a kitchen, used oil is left in open containers. A fire breaks out when someone lights a nearby stove.* What lesson about fire safety and housekeeping does this scenario illustrate?
17. *An employee cannot find a clean, working wrench and wastes 20 minutes searching through a pile of unorganised tools.* How does poor housekeeping affect efficiency and time management?
18. *In a storeroom, boxes are stacked haphazardly. One collapses and injures a student's foot.* What housekeeping principle was violated, and what is the result?
19. *During a fire drill, employees struggle to exit because the emergency exit is blocked by unused furniture and storage boxes.* What is the safety risk of poor housekeeping during emergencies?
20. *A dusty shelf in the maintenance room is left unattended for months. A worker develops respiratory problems after frequent exposure.* What health risk does this example highlight, and how is it linked to housekeeping?

21. At a construction site, wooden planks and nails are scattered along the walkway. A worker steps on a nail and gets injured. What housekeeping rule was violated, and how could this incident have been prevented?
22. During heavy rain, unused cement bags are left uncovered on-site and become damaged. What housekeeping lesson can be learned from this situation?
23. An electric drill was left plugged in and lying on the ground at a busy construction zone.

What safety risk does this pose, and what is the proper housekeeping rule?

24. A worker slips on spilt oil near a machine. The spill was not cleaned up after a maintenance task. Which housekeeping rule applies here, and why is it important?
25. Boxes of raw materials are stacked haphazardly in the production area, causing one to fall and injure a worker. What went wrong, and what does good housekeeping require in this case?
26. Hazardous cleaning agents are stored in unlabelled bottles in a manufacturing storeroom. How is this a violation of housekeeping rules?
27. An employee trips over tangled computer cords in an office aisle. What housekeeping practice was ignored, and what is the proper action?
28. Stacks of paper and files are piled around a desk, and one stack topples onto a nearby heater. What risk does this pose, and what's the correct housekeeping approach?
29. Fire extinguishers in the office are blocked by a storage cabinet and cannot be accessed easily. Why is this poor housekeeping, and what's the potential consequence?
30. Overflowing trash bins in the break room emit bad odours and attract insects. Which housekeeping rule is being broken, and why does it matter?
31. A worker in the school's maintenance room accidentally cuts their hand deeply with a box cutter. The wound is bleeding heavily. What immediate actions should you take to control the bleeding and prevent infection?
32. A student in the lab touches a hot metal rod and suffers a minor burn on their palm. How should you treat this burn to reduce pain and prevent further damage?
33. A technician is electrocuted while using faulty equipment. The victim collapses and is unresponsive. What steps must you follow to ensure your safety and provide first aid?
34. A worker falls from a low ladder and complains of severe pain in their leg. The leg appears swollen and slightly twisted. What should you do while waiting for medical professionals to arrive?
35. A student complains that a metal shaving flew into their eye during a workshop session. What first aid steps should you take, and what must you avoid doing?
36. While lifting a box, a worker twists their ankle. The ankle is swollen, painful, and difficult to move. How do you provide immediate care to reduce swelling and promote healing?
37. During lunch break, a co-worker begins choking on food. They are unable to speak or breathe and are signalling for help. What actions should you take to relieve the obstruction?
38. A cleaning staff member splashes cleaning chemical into their eye and begins screaming in pain. What should be your immediate first aid response and follow-up?

39. A worker becomes unconscious after working in a poorly ventilated room with strong fumes. How should you respond to this situation without putting yourself at risk?
40. A technician suffers a small cut from a rusty metal sheet. Why is this injury still serious, and what steps should be taken even if the cut is minor?

SECTION

3

PROFESSIONAL ETHICS

ETHICS AND PROFESSIONAL PRACTICE

INTRODUCTION

Ethics and professional conduct are fundamental to engineering practice. Engineering institutions, such as the Ghana Institution of Engineering (GhIE), establish ethical guidelines to ensure engineers uphold integrity, safety, and accountability in their work. These principles protect public welfare, guide professional behaviour, and maintain trust in engineering solutions that shape society. Learning about ethics fosters responsible decision-making, critical thinking, and a commitment to professionalism. It also prepares you for future challenges in engineering careers. In this section, ethical guidelines and professional practice around Integrity, Public Safety, Competence, Accountability and Sustainability will be explored. You will be able to adhere to ethical standards set by engineering institutions and maintain confidentiality. This section will explore ethical guidelines and professional practice around Integrity, Public Safety, Competence, Accountability and Sustainability and respect intellectual property rights, as well as avoid conflicts of interest and act in the best interest of society.

KEY IDEAS

- **Importance of Professional Codes of Ethics:** These codes help maintain public trust, protect human and environmental well-being, and uphold the dignity of the profession.
- **Mandate of Professional Bodies:** Their responsibilities include registering engineers, enforcing codes of ethics, setting professional standards, and promoting continuous professional development.
- **Nature of Professional Codes of Ethics:** A code of ethics is a structured set of moral principles and professional rules that engineers are expected to follow in their work.
- **Professional Bodies in Engineering:** These are official organisations that oversee and regulate the engineering profession to ensure standards of competence, safety, and integrity.
- **Structure of a Code of Ethics:** Most codes include sections on honesty, fairness, confidentiality, conflict of interest, responsibility to the public, and professional accountability.

DESCRIBE THE NATURE, RELEVANCE, AND MANDATE OF PROFESSIONAL BODIES

Nature of Professional Bodies

Professional bodies are formal organisations that represent individuals who work in specific professions, such as engineering, law, medicine, accounting, or education. These organisations are usually non-profit, member-driven, and are often governed by elected councils or boards. Their nature is to act as custodians of professional standards, knowledge, and ethics, supporting the continuous development and recognition of their members. It sets rules, standards, and ethics for the profession and supports the professional development of its members.

These are some professional bodies in Ghana.

1. **Ghana Institution of Engineering (GhIE)** – for engineers.
2. **Institution of Engineering and Technology (IET)** - for engineers
3. **Ghana Bar Association (GBA)** – for lawyers.
4. **Ghana Medical Association (GMA)** – for medical doctors.
5. **Pharmaceutical Society of Ghana (PSGH)** – for pharmacists.
6. **Ghana Institute of Architects (GIA)** – for architects.
7. **Ghana Institute of Surveyors (GhIS)** – for surveyors.
8. **Ghana Chartered Institute of Bankers (CIB Ghana)** – for banking professionals.
9. **Ghana Institute of Journalism (GIJ)** (also functions partly as a professional training body for journalists).
10. **Institute of Chartered Accountants, Ghana (ICAG)** – for accountants.
11. **Chartered Institute of Marketing, Ghana (CIMG)** – for marketing professionals.
12. **Ghana Psychological Association (GPA)** – for psychologists.
13. **Ghana Nurses and Midwives Association (GNMA)** – for nurses and midwives.
14. **Chartered Institute of Human Resource Management, Ghana (CIHRM)** – for HR professionals.
15. **Ghana National Association of Teachers (GNAT)** - for teachers.
16. **University Teachers Association of Ghana (UTAG)** - for university lecturers.
17. **Technical University Teachers Association of Ghana (TUTAG)** - for technical university teachers.

Relevance of Professional Bodies

Professional bodies are highly relevant because they:

1. Ensure professionals maintain high standards of practice and conduct.
2. Promote ethical behaviour by enforcing codes of ethics and professional responsibility.
3. Support continuous professional development through training, workshops, and seminars.

4. Provide certification and licensing to prove qualifications and competence.
5. Build public trust by ensuring professionals are qualified and accountable.
6. Offer networking opportunities through conferences and professional events.
7. Represent the interests of professionals in discussions with government and industry.
8. Enforce disciplinary actions when members break professional or ethical rules.
9. Encourage research and innovation within various professional fields.
10. Enhance the image and credibility of the profession in society.

Mandate of Professional Bodies

Typically, professional bodies have the following mandates.

1. Set and maintain professional standards and best practices.
2. Regulate entry into the profession through examinations, licensing, and registration.
3. Develop and enforce a code of ethics and professional conduct.
4. Certify and accredit qualified professionals.
5. Ensure continuous professional development (CPD) of members.
6. Monitor and discipline members for professional misconduct.
7. Promote public interest and safety through quality professional services.
8. Represent and advocate for the interests of the profession.
9. Support research, innovation, and knowledge sharing within the profession.
10. Provide networking and collaboration opportunities for professionals.

Activity 3.1 Group Research and Poster Creation

Objective: To research and present the nature, relevance, and mandate of specific professional bodies.

Materials Needed: Chart paper, markers, internet access or printed materials.

Steps

1. Join a small group.
2. Each group will be assigned a different professional body in Ghana.
3. Research the nature, relevance, and mandate of that body.
4. Create and present a poster summarising their findings.
5. Display the posters around the classroom.

Questions

1. What is the main function of this professional body?
2. How does it support its members and the public?
3. What makes it unique?

Activity 3.2 Case Study of Unethical Behaviour

Objective: To explore the role of professional bodies in enforcing ethical conduct.

Materials Needed: Case study handout about a professional behaving unethically.

Steps

1. Join a small group.
2. A scenario will be provided where a professional violates a code of ethics.
3. In your group, discuss what the professional body should do.
4. Each group presents its recommendations in 5 minutes.

Questions

1. What rules were broken in the scenario?
2. What actions can the professional body take?
3. How do professional bodies protect the public?

Activity 3.3 Importance of Professional Bodies in Protecting Society

Objective: To analyse how professional bodies contribute to public trust and safety.

Materials Needed: Worksheet with prompts.

Steps

1. Think individually about how professional bodies protect society.
2. Pair up to discuss your ideas.
3. Share with the class.

Questions

1. How do professional bodies ensure public safety?
2. Can society function well without professional bodies?

Activity 3.4 Mandate Matching Game

Objective: To match professional bodies with their specific mandates.

Materials Needed: Cards with the names of professional bodies and cards with mandates.

Steps

1. Cards are distributed randomly in the classroom.
2. Walk around and find the matches.
3. Once matched, each pair explains their professional body and mandate to the class.

Questions

1. Why is this mandate important?
2. How does it support professional standards?

Activity 3.5 Professional Body Fair (Gallery Walk)

Objective: To showcase and explore various professional bodies.

Materials Needed: Tables, printed materials, props, posters.

Steps

1. Join a small group.
2. Each group will be assigned a professional body to represent.
3. Groups prepare booths with visuals and talking points.
4. Class walks around the room visiting each booth.
5. Complete a worksheet with questions at each station.

Questions

1. What is the purpose of this professional body?
2. What are the benefits of membership?

Activity 3.6 Debate – Are Professional Bodies Still Relevant?

Objective: To evaluate the ongoing relevance of professional bodies.

Materials Needed: Debate format guidelines, research materials.

Steps

1. Divide into two debate teams.
2. One side argues that professional bodies are essential today, the other that they are less important now.
3. Conduct the debate and have the class vote.
4. Each debate team is given a maximum of 10 minutes.

Questions

1. Are professional bodies adapting to today's challenges?
2. What would happen if professional bodies did not exist?

Activity 3.7 Create a Code of Ethics

Objective: To understand the ethical role of professional bodies.

Materials Needed: Paper, markers, and sample codes of ethics.

Steps

1. Join a small group.
2. In your group, choose a profession.
3. Create a basic code of ethics that a professional body might enforce.
4. Groups present their codes and explain the reasoning.

Questions

1. Why are these ethical rules important?
2. How do they protect professionals and the public?

Activity 3.8 Timeline Activity – History of a Professional Body

Objective: To trace the development and impact of a professional body.

Materials Needed: Timeline templates, internet/library resources.

Steps

1. Join a small group.
2. Your group is assigned to research the history of a Ghanaian professional body.
3. Groups create a timeline showing key events, changes, and achievements.
4. Timelines are displayed and discussed in class.

Questions

1. How has the professional body evolved over time?
2. What milestones improved the profession or society?

The importance and nature of a professional code of ethics

Importance of a Professional Code of Ethics

A code of ethics helps professionals know how to behave in the right way.

- a. Helps people trust professionals by showing they are honest and responsible.
- b. Encourages good behaviour and high standards at work.
- c. Protects clients and the public from wrong or harmful actions.
- d. Gives guidance when making difficult decisions.
- e. Makes the profession look good by promoting ethical behaviour.

- f. Makes it clear what happens when someone breaks the rules.
- g. Helps professionals manage themselves, so there is less need for outside control.

Nature of a Professional Code of Ethics

A professional code of ethics is a set of rules that guides how professionals should behave and make decisions. It explains what is right and wrong in a job. These rules are made by professional bodies, and all members must follow them.

The code of ethics is

- a. **Prescriptive** – It tells professionals the right way to behave.
- b. **Protective** – It helps keep clients and the public safe.
- c. **Guiding** – It supports professionals when they face difficult choices.
- d. **Binding** – All members must follow it, or they may face punishment.

Activity 3.9 Website Exploration

Objective: You will explore and interpret real codes of ethics used by engineering professional bodies.

Materials Needed: Internet-enabled devices, links to GhIE (<https://ghie.org.gh>), ICE (<https://www.ice.org.uk>), or IEEE (<https://www.ieee.org>).

Steps

1. In pairs, visit a professional engineering body's website.
2. Search for and read their code of ethics.
3. Summarise key principles (e.g., honesty, public safety, integrity).
4. Share summaries with the class.

Questions

1. What are three key values found in this code of ethics?
2. How do these values support professional behaviour in engineering?
3. What might happen if these principles are ignored?

Activity 3.10 Think-Pair-Share

Objective: To reflect on the purpose of professional codes of ethics.

Materials Needed: Short prompt or scenario (e.g., an engineer discovers a safety flaw).

Steps

1. Think individually about how to respond ethically.
2. Pair with a partner to compare ideas.

3. Share responses with the class.

Questions

1. Why is it important for professionals to act ethically?
2. How does a code of ethics help with decision-making?

Activity 3.11 Case Study Analysis

Objective: To evaluate the consequences of breaking a code of ethics.

Materials Needed: Printed case study (e.g., a collapsed bridge due to poor engineering).

Steps

1. Read a real or fictional story of unethical behaviour.
2. Divide into small groups.
3. Groups analyse what rules were broken and what the consequences were.
4. Present findings.

Questions

1. What specific code of ethics was violated?
2. Who was affected by the unethical behaviour?
3. What lessons can we learn?

Activity 3.12 Ethics vs Conduct – Know the Difference

Objective: To identify and explain the difference between a code of ethics and a code of conduct by creating examples for a fictional profession.

Materials Needed: Chart paper or whiteboards, markers, sticky notes

Steps

1. Divide into small groups.
2. Choose a fictional or real profession
3. Create two separate lists;
 - a. Code of Ethics – 3–5 core values or principles guiding the professional's mindset (e.g., honesty, integrity, respect for life).
 - b. Code of Conduct – 3-5 behavioural rules or expectations (e.g., never operate a drone near crowds, always wear safety gear).
4. Label and display both lists clearly on your chart paper.
5. Present to the class, explaining the distinction between your ethical principles and conduct rules.

Questions

1. What is the difference between a code of ethics and a code of conduct?
2. Why are both important in a profession?
3. How do ethics influence the rules in a code of conduct?
4. Why did you include each rule?
5. How do your rules protect clients, the public, and the profession?

Activity 3.13 Interview a Professional

Objective: To connect ethical theory to real-world application.

Materials Needed: Guest speaker or printed interview excerpts from professionals.

Steps

1. Invite an engineer or technician to speak about ethics in their work.
2. Prepare and ask questions.
3. Reflect as a class on what was shared.

Questions

1. What ethical challenges does the professional face?
2. How do they apply their code of ethics in daily work?

Activity 3.14 Ethics Violation Tribunal Simulation

Objective: To apply a code of ethics to judge professional conduct.

Materials Needed: Mock tribunal setup, case file of a professional accused of misconduct.

Steps

1. You will be assigned to a role: ethics panel, accused professional, or witness.
2. A case of misconduct is presented.
3. The tribunal decides whether ethics were violated and what action to take.

Questions

1. Was the code of ethics clearly violated?
2. What would be a fair and professional consequence?

Activity 3.15 Ethics Poster Campaign

Objective: To promote awareness of ethical behaviour through visual media.

Materials Needed: Posters, markers, and design tools.

Steps

1. Join a small group.
2. Groups create posters that teach or promote one ethical principle (e.g., integrity, honesty).
3. Posters are displayed in class.
4. Each group explains their message.

Questions

1. Why did you choose this ethical value?
2. How does this value help society?

Activity 3.16 Code of Ethics Matching Game

Objective: To become familiar with different ethical principles and their meanings.

Materials Needed: Printed cards (half with ethics terms, half with definitions or examples).

Steps

1. The cards are distributed randomly to the whole class.
2. Take your card (either an ethical term or a definition) and find your matching partner.
3. Each pair explains their term and gives a real-world example.

Questions

1. What does your term mean in a professional context?
2. Can you give an example where this principle applies?

DETERMINING WHETHER OR NOT CONDUCT VIOLATES A CODE OF ETHICS

To determine whether or not conduct violates a code of ethics, you should:

1. Identify the Relevant Ethical Principles

Look at the code of ethics and figure out which parts relate to the situation—for example, honesty, safety, or professionalism.

2. Describe the Conduct Clearly

Explain what happened in simple terms. Who was involved? What did the person do?

3. Compare the Conduct with the Ethical Standards

Ask: Did the person act in a way that matches what the code of ethics expects? Were they honest, respectful, and responsible?

4. Assess the Impact

Think about the results of the action. Did anyone get hurt—like a client, the public, or the environment? Was trust broken or safety ignored?

5. Make a Judgment

Decide: If the person clearly went against the rules (for example, lied, took shortcuts, or acted unprofessionally), then they broke the code. If they followed the values, they did not break the code.

6. Check for Disciplinary Guidelines

Look at what the professional body (like GhIE) says about consequences. What happens if someone breaks the code? Are there punishments or actions taken?

Examples of some conduct that violates the professional code of ethics

Engineering (Ghana Institution of Engineers - GhIE)

Scenario: An engineer signs off a structural drawing for a building they did not review or design.

Violation? *Yes*

Code Breached: GhIE Code of Ethics– **Section 2.1(a)** – Members shall only undertake assignments they are competent to perform.

Analysis: Engineers must only approve work they have checked and believe is safe.

Consequence: Suspension or removal from GhIE register.

Teaching (Ghana Education Service - GES)

Scenario: A teacher accepts money from students in exchange for better grades.

Violation? *Yes*

Code Breached: GES Code of Conduct – **Regulation 3.1(b)** – A teacher shall not accept any gift or favour that may influence professional judgment.

Analysis: This is bribery and damages fairness in education.

Consequence: Dismissal from service.

Nursing (Nursing and Midwifery Council of Ghana)

Scenario: A nurse shares private patient information on social media without permission.

Violation? Yes

Code Breached: NMC Code of Ethics – **Principle 5.1** – Nurses must maintain patient confidentiality at all times.

Analysis: Patient confidentiality must always be protected.

Consequence: Suspension or cancellation of license.

Journalism (Ghana Journalists Association - GJA)

Scenario: A journalist publishes a story without verifying the facts, causing public panic.

Violation? Yes

Code Breached: GJA Code of Ethics – **Article 1** – A journalist shall take every precaution to ensure accuracy.

Analysis: Journalists must verify information before publishing.

Consequence: Public apology, fine, or removal from GJA.

Medical Profession (Medical and Dental Council of Ghana)

Scenario: A doctor prescribes medicine without examining the patient.

Violation? Yes

Code Breached: MDC Code of Ethics – **Section 3.2** – Practitioners must conduct proper clinical assessment before treatment.

Analysis: Doctors must not treat or prescribe without proper assessment.

Consequence: Disciplinary hearing or license suspension.

Accountancy (Institute of Chartered Accountants, Ghana - ICAG)

Scenario: An accountant hides a company's losses in financial statements to attract investors.

Violation? Yes

Code Breached: ICAG Code of Ethics – **Part A, Section 110.1** – A professional accountant shall be straightforward and honest.

Analysis: This is financial misrepresentation and dishonest.

Consequence: License revocation or legal prosecution.

Surveying (Ghana Institution of Surveyors)

Scenario: A surveyor changes land boundaries in favour of a client without permission.

Violation? Yes

Code Breached: GIS Code of Conduct – **Clause 2.2** – Surveyors shall provide accurate and truthful information.

Analysis: Surveyors must give correct data and avoid fraud.

Consequence: Disciplinary sanctions or court action.

Police Service (Ghana Police Service Code of Conduct)

Scenario: A police officer uses unnecessary force on an unarmed person during an arrest.

Violation? *Yes*

Code Breached: Police Code of Ethics – **Section 2.3** – Officers must use only reasonable and necessary force.

Analysis: Officers must use only reasonable and necessary force.

Consequence: Suspension, demotion, or dismissal.

Pharmacy (Pharmacy Council of Ghana)

Scenario: A pharmacist sells prescription drugs without a doctor's prescription.

Violation? *Yes*

Code Breached: Pharmacy Council Code – **Regulation 6(1)(a)** – Pharmacists must dispense only with valid prescriptions.

Analysis: Selling such drugs without a prescription is illegal and dangerous.

Consequence: Fine, suspension, or closure of the pharmacy.

Architecture (Ghana Institute of Architects)

Scenario: An architect copies another designer's building plans and claims it as their own.

Violation? *Yes*

Code Breached: GIA Code of Ethics – **Rule 3.4** – Members shall respect the intellectual property rights of others.

Analysis: This is plagiarism and dishonest professional behaviour.

Consequence: Disciplinary measures or legal action.

Activity 3.17 Ethics Violation or Not?

Objective: To classify scenarios as ethical or unethical.

Materials Needed: Printed cards with different professional conduct scenarios.

Steps

1. Distribute scenario cards to your group.
2. Each group reads and discusses each situation.
3. Groups sort scenarios into "Ethical" and "Unethical" categories.
4. Class discusses each classification.

Questions

1. What values were upheld or violated in this scenario?
2. Does this action go against a known code of ethics?
3. What might be the real-world consequence?

Activity 3.18 Think-Pair-Share

Objective: To critically assess a situation involving questionable conduct.

Materials Needed: Printed ethical dilemmas.

Steps

1. Read a short scenario individually.
2. Think about whether it violates ethics.
3. Pair up to share and compare views.
4. Share with the class.

Questions

1. What part of the code might this behaviour violate?
2. Can intention justify the action taken?

Activity 3.19 True or False?

Objective: To recognise violations of ethical standards.

Materials Needed: Quiz sheets with statements/actions based on codes of ethics.

Steps

1. Individually complete a quiz determining if actions are ethical.
2. Discuss answers in a small group.
3. Go over answers as a class, with reference to the ethics code.

Questions

1. Why is this statement true or false?
2. What principle is being followed or broken?

Activity 3.20 Research and Report

Objective: To analyse real-world cases of ethical misconduct.

Materials Needed: Internet access, newspaper clippings or summarised cases.

Steps:

1. Assign you to research local professional misconduct stories.

2. Identify what ethical rules were violated.
3. Present findings to the class.

Questions

1. What rule was broken?
2. Who was affected by the violation?
3. What action was taken?

Activity 3.21 Peer Code Review

Objective: To examine and critique each other's understanding of ethical conduct.

Materials Needed: Custom-written scenarios by the group.

Steps

1. Join a small group.
2. Each group writes a professional conduct scenario.
3. Exchange with another group for evaluation.
4. Receiving groups determine if the behaviour violates ethics.
5. Share feedback.

Questions

1. What makes this scenario ethical or unethical?
2. What rule does it align with or break?

Activity 3.22 Ethics Wheel

Objective: To apply ethical decision-making under random scenarios.

Materials Needed: A spinning wheel (physical or digital) with scenarios.

Steps

1. A group spins the wheel and reads the scenario it lands on.
2. They determine if it violates a code of ethics and justify.
3. Other groups can challenge the judgment.

Questions

1. Does the scenario show integrity and responsibility?
2. Could the behaviour harm others or the profession?

Activity 3.23 “Ethics Detective” Card Match

Materials Needed

1. Set of **scenario cards** (short real-world engineering situations)
2. Set of **code of ethics cards** (summarised ethical principles from a professional body such as GhIE)
3. Large sorting mat or table labelled
 - a. Ethical | Unethical
 - b. Which code was upheld or violated?

Steps

1. **Introduction**
 - a. Remember that professional bodies guide conduct using codes of ethics.
 - b. Briefly highlight GhIE or IEEE as an example.
2. **Group Work**
 - a. Divide yourselves into smaller groups.
 - b. Each group receives.
 - i. 3–4 **scenario cards**
 - ii. 3–4 **code of ethics cards**
 - c. Task
 - i. Each group read each scenario.
 - ii. Decide if it's **ethical or unethical**.
 - iii. Match it with the relevant code of ethics (e.g., safety, honesty, competence).
3. **Class Sharing (2 min)**
 - a. One or two groups share an example.
 - b. Discussion to clarify links to professional conduct and relevance of professional bodies.

Questions

1. What makes this behaviour ethical or unethical?
2. Which professional code of ethics does this conduct relate to?
3. What role would a professional body play in this case?

EXTENDED READING

- Encyclopaedia of Business and Professional Ethics. (2023). Germany: Springer International Publishing.
- Soni, M. (2024). Professional Pathways Skills and Ethics. India: Poorav Publications.

REVIEW QUESTIONS

1. A student named Kwesi wants to become an electrical engineer. His teacher advises him to register with the Ghana Institution of Engineering (GhIE) after his studies. What is the relevance of Kwesi joining a professional body like GhIE?
2. Ama, an electrical technician, is being accused of misconduct. The Ghana Electrical Contractors Association (GECA) is reviewing the case. What mandate does GECA have in such a situation?
3. Yaw asks his teacher why professional bodies exist when people can get jobs with just a certificate. How should the teacher explain the nature and mandate of professional bodies?
4. A civil engineer is being consulted on a bridge project. The client prefers engineers who are members of a professional body. Why might clients prefer professionals who are members of registered bodies?
5. After completing her diploma in building technology, Abena wants to register with a professional body but is unsure what benefits it brings. How can professional bodies support her career growth?
6. A journalist writes that engineers in Ghana should be held accountable for unsafe buildings. What role can a professional body play in ensuring accountability?
7. A group of engineering students want to establish a robotics club and reach out to the GhIE for support. Why might a professional body be interested in supporting students?
8. An engineer proposes a new building design that violates safety rules. His supervisor reports him to their professional body. What does this action show about the relevance of professional bodies?
9. A teacher gives students a task to compare two professional bodies: GhIE and the Ghana Bar Association. What similar mandate do these bodies share?
10. During career day, a speaker says: “Without professional bodies, there would be chaos in the professions.” Do you agree or disagree? Justify your answer using the mandate of professional bodies.
11. Kojo is training as a civil engineer. He notices his supervisor ignoring safety regulations on a building site. According to a professional code of ethics, what should Kojo do?
12. Akosua reads that engineers must avoid conflicts of interest. What does this tell you about the nature of a professional code of ethics?
13. Yaw, a young electrical apprentice, tells a lie about completing a task just to impress his boss. Why is this behaviour against the professional code of ethics?
14. A building contractor uses cheap materials instead of the approved quality ones. Why is this a violation of the code of ethics?
15. A new engineer refuses to share credit with the rest of her team after a successful project. What ethical principle is being ignored?
16. Kwame wants to know why engineers must follow a code of ethics. Explain one importance of a professional code of ethics.

17. Ama says: “Engineers should follow the law, not ethics.” Do you agree? Why or why not?
18. A group of students wants to include a code of conduct in their robotics club.
Question: How does this reflect the nature of a professional code of ethics?
19. A client offers a bribe to a contractor to finish work faster. What should the contractor do according to professional ethics?
20. A civil engineering student presents fake certificates to secure a job. How does this action relate to the professional code of ethics?
21. An engineer discovers a calculation error in a bridge design after it has been approved but decides not to report it, thinking it is minor. Does this action violate the code of ethics? Explain your reasoning.
22. A construction manager gives a contract to a friend’s company without considering other qualified bidders. Is this ethical? Why or why not?
23. An engineering student uses parts of another student’s project and presents it as their own in a competition. Does this violate a professional code of ethics? Why?
24. A technician refuses to perform a task they are not trained or certified for and reports the issue to a supervisor. Does this align with professional ethical conduct?
25. An engineer accepts a gift from a supplier shortly after awarding them a contract. Does this raise ethical concerns? Why?
26. A contractor inflates the quantity of materials used in a project to charge the client more. Does this violate the code of ethics? Explain.
27. A supervisor ignores a junior worker’s safety complaint and asks them to continue working in unsafe conditions. Is this behaviour ethical? Why or why not?
28. An engineer refuses to falsify a test result even after being pressured by their manager. Does this demonstrate ethical conduct? Why?
29. An engineering consultant advertises their services using exaggerated claims of success and qualifications. Is this ethical? Provide your reasoning.
30. During a team project, one member takes credit for a solution that was developed by another teammate. Does this action violate professional ethics?



SECTION

4

ENERGY SYSTEMS

CIRCUITS AND MACHINES

INTRODUCTION

In this section, you will learn about different types of electrical machines, how they are used, and how they work. Electrical machines are devices that change electrical energy into mechanical energy, or mechanical energy into electrical energy. You will explore machines like transformers, motors, generators, and special machines such as stepper and servo motors, and understand their roles in everyday systems. You will also learn how to connect these machines to power, control how they run, and safely disconnect them when needed. Safety is very important when working with electrical machines, so you will be taught the right steps to stay safe and prevent accidents.

KEY IDEAS

- **Classification and Identification of Electrical Machines:** Electrical machines include motors, generators, and transformers.

They are classified as: DC and AC motors (e.g., induction, synchronous), DC and AC generators (e.g., alternators), and special machines like stepper motors and servo motors.

Each type has unique features and specific uses in electrical systems.

- **Functions and Applications of Electrical Machines:** Transformers are used to step up or step down voltage for power transmission and distribution.

Motors (DC/AC) convert electricity into motion for machines, tools, and appliances.

Generators convert mechanical energy into electricity for homes, industries, and backup systems.

Stepper and servo motors enable accurate motion control in devices like 3D printers, robotics, and CNC machines.

- **Operation and Control of Electrical Machines:** Machines must be properly connected using the correct voltage and protective devices.

Controlled through switches, contactors, relays, or automation systems.

Safe disconnection includes shutting off power, discharging energy, and following proper procedures.

- **Safety Measures in Handling Electrical Machines:** Always wear personal protective equipment (PPE) like gloves and insulated boots.

Use circuit breakers, ensure grounding, and follow manufacturer guidelines.

Maintain machines regularly, display safety signs, and train users to avoid accidents and equipment damage.

ELECTRICAL MACHINES

Electrical machines are devices that convert electrical energy into mechanical energy or vice versa. They can also transform electrical energy from one form to another. These machines are generally grouped based on their functions.

Electric Motors

Electric motors are machines that change electrical energy into mechanical energy. They work by creating movement through the interaction of a magnetic field and electric current.

Types of Electric Motors

1. AC Motors (e.g., induction motors, synchronous motors)

AC motors convert alternating current (AC) into mechanical energy.

Types of AC Motors

- a. **Induction Motors:** These are the most used motors and are self-starting.
 - i. **Single-phase induction motors:** Used in household items like fans and washing machines.
 - ii. **Three-phase induction motors:** Used in factories for heavy machinery.
- a. **Synchronous Motors:** These motors run at a constant speed and are used where speed accuracy is important.

Practical Examples

- a. **Ceiling fan:** Works using a single-phase induction motor.
- b. **Industrial air compressor:** Uses a three-phase AC motor to handle large loads.



Figure 4.1: A picture of an AC motor

2. **DC Motors (e.g., series, shunt, compound motors):** A DC motor is a type of electrical machine that changes direct current (DC) into mechanical energy. It works based on the principle that a wire carrying current inside a magnetic field feels a force, which makes it spin or rotate.

Types of DC Motors

- Shunt DC Motor:** Runs at a steady (constant) speed.
- Series DC Motor:** Provides strong starting power (high torque).
- Compound DC Motor:** Combines the features of both shunt and series motors.

Practical Examples

- Electric wheelchair:** Uses a DC motor to allow smooth and accurate movement.
- Conveyor belts:** Use DC motors where speed needs to be adjusted depending on the task.

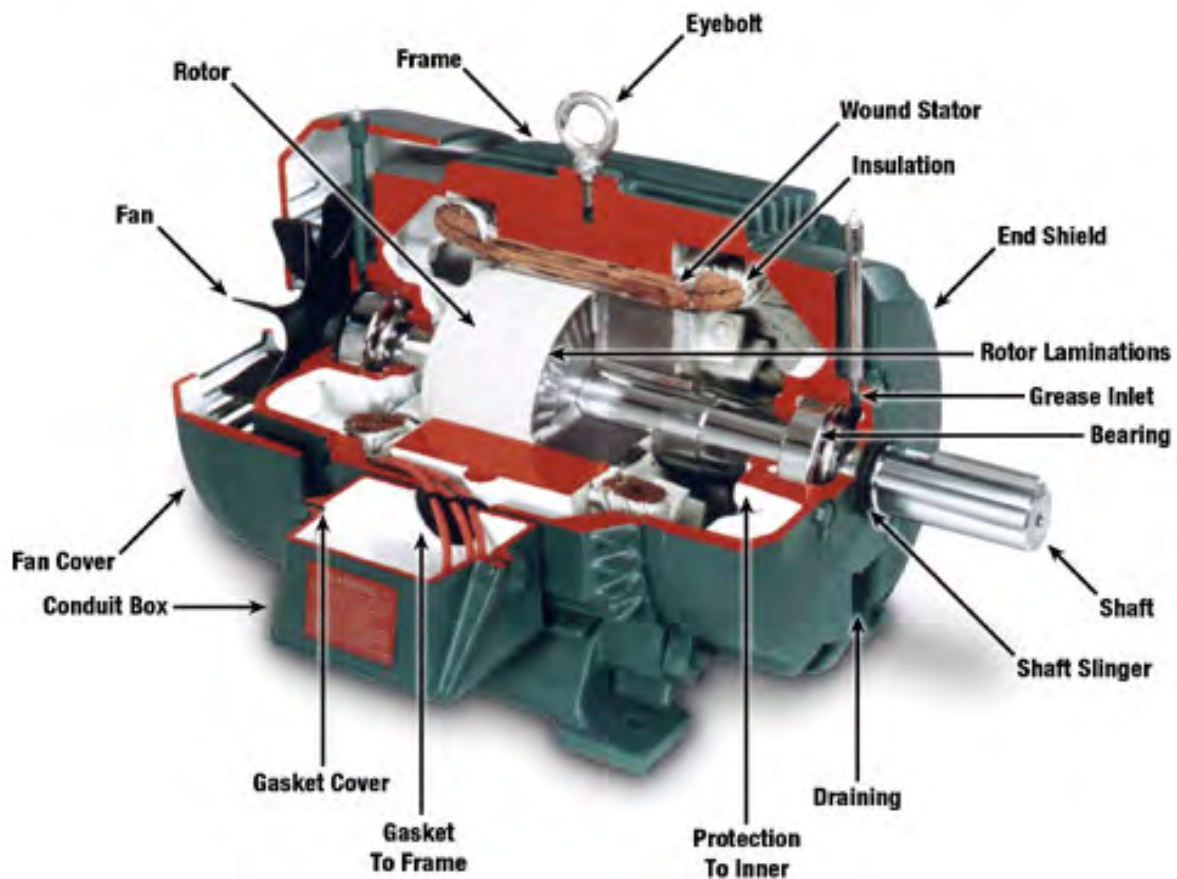


Figure 4.2: Picture of DC motor

Electric Generators

Electric generators are machines that change mechanical energy (like motion) into electrical energy.

Types of Generators

1. **DC Generator:** Produces direct current (DC) electricity from mechanical energy.

Types of DC Generators

- a. **Shunt-Wound Generator:** Gives a steady (constant) voltage.
- b. **Series-Wound Generator:** Voltage changes with load (variable voltage).
- c. **Compound-Wound Generator:** Combines both shunt and series features.

Practical Examples

- a. Wind-up flashlights or bicycles that generate power to charge a battery.
- b. Older train coaches that use DC generators to power lights and fans

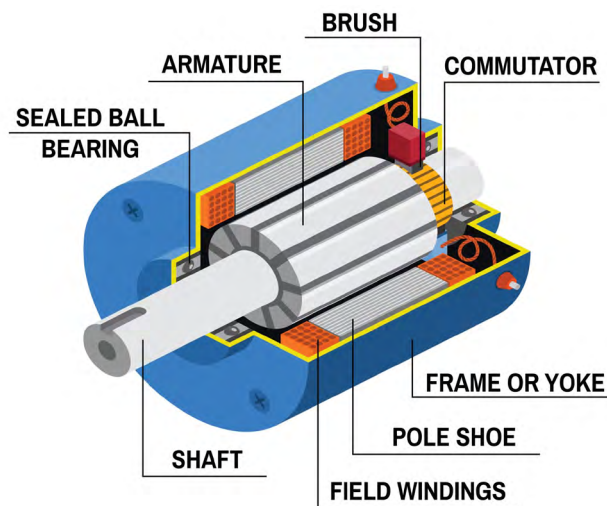


Figure 4.3: Picture of a DC generator

2. **AC Generators (Alternators):** AC generators are machines that change mechanical energy into alternating current (AC) electricity.

Types of AC Generators

- a. **Single-Phase Alternator:** Used for small devices or homes.
- b. **Three-Phase Alternator:** Used in factories and power stations.

Practical Examples

- a. **Diesel generators** in hospitals provide backup AC power when the lights go out.
- b. **Wind turbines** use alternators to turn wind energy into AC electricity.

Activity 4.1 Watch and Analyse an Educational Video

Objective: To visually understand how various electrical machines function.

Materials Needed

- Projector/screen
- Video on electrical machines (see below)
- Worksheet for notes

Steps

1. Play an educational video explaining different machines.
2. Pause after each section to discuss key concepts with your classmates.
3. Take notes on the worksheet.
4. Review and reflect afterwards.
5. Video Suggestion: https://youtu.be/SVTq5mjclPo?si=4Et1w_YyH7wzFW4m



Questions

1. What are the three main types of electrical machines introduced in the video?
2. How are generators classified? What distinguishes an AC generator from a DC generator?
3. Can you name two differences between a motor and a transformer?
4. What is the main difference between motors and generators?

Activity 4.2 Electrical Machine Scavenger Hunt

Objective: To identify different electrical machines commonly used in your environment.

Materials Needed

- Scavenger Hunt worksheet
- Pens/pencils
- Access to school lab or workshop
- Camera or phone (optional)

Steps

1. Join a small group.

2. Each group will be given a worksheet listing different types of electrical machines (e.g., transformer, motor, generator, alternator, etc.).
3. Ask them to search the school, workshop, or nearby environment to find and photograph or sketch the listed machines.
4. Each group should fill in the name, function, and location of each item found.
5. Regroup in class to share findings.

Questions

1. Which electrical machine was the easiest to find? Why?
2. What function does a transformer serve in a circuit?
3. Did you find any machine that surprised you?

Activity 4.3 Electrical Machine Matching Game

Objective: To match electrical machines with their functions and components.

Materials Needed

- Printed cards with the names of machines
- Cards with images
- Cards with functions

Steps

1. Sets of cards (name, image, function) for each type of electrical machine will have been created.
2. The cards will be shuffled and distributed randomly among the groups.
3. In your group, match the correct name, image, and function of each electrical machine.
4. Discuss answers as a class.

Questions

1. What helped you identify the right match?
2. How does the function differ between a generator and a motor?

Activity 4.4 Hands-On Demonstration Using Models

Objective: To demonstrate the operation of different types of electrical machines.

Materials Needed

- Small models of motors, generators, transformers, etc.
- Power source
- Multimeter

Steps

1. Different electrical machine models will have been set up in the lab.
2. Each machine's function will be demonstrated with a brief explanation.
3. Operate each machine under supervision.
4. Measure voltage/current using a multimeter.

Questions

1. What happens when you rotate the shaft of the generator?
2. What readings do you get from the transformer input/output?

Activity 4.5 Field Trip to Electrical Workshop or Industry

Objective: To identify real-life electrical machines in industrial settings.

Materials Needed

- Notebooks
- Pens
- Safety gear (helmet, vest)

Steps

1. Arrange a field visit to a local electrical workshop, power station, or factory.
2. Observe and note the machines in use.
3. Have professionals explain how each machine works.
4. Sketch machines and record observations.

Questions

1. Which machine seemed most important to the facility? Why?
2. What was new or unexpected about the machines you saw?

Activity 4.6 Create a Poster on Types of Electrical Machines

Objective: To visually categorise electrical machines.

Materials Needed

- Poster paper
- Markers
- Magazines/internet printouts
- Glue

Steps

1. Join a small group.

2. Research and categorise machines into: AC machines, DC machines, and static machines (transformers).
3. Create a poster that includes images, types, and uses of each.
4. As a group, present your poster to the class in 5 minutes.

Questions

1. What is the main difference between static and rotating machines?
2. What machine did your group enjoy learning about most?

Activity 4.7 Build a Simple DC Motor

Objective: To understand the working principle of a DC motor.

Materials Needed

- Copper wire
- Battery
- Magnets
- Paper clips
- Tape

Steps

1. Wind the copper wire into a coil.
2. Mount the coil using paper clips as supports.
3. Place magnets beneath the coil.
4. Connect to a battery and observe the coil spin.
5. Discuss electromagnetic interaction.

Questions

1. What causes the coil to spin?
2. What would happen if the magnets were removed?

Activity 4.8 Classify Electrical Machines Chart

Objective: To reinforce classification skills for different electrical machines.

Materials Needed

- Chart template
- Markers
- Sample machine names

Steps

1. Create a table with columns: Machine Name, Type (AC/DC/Static), Use, Voltage Rating.
2. Provide names/images of machines.
3. Fill in the chart with research or prior knowledge.
4. Share and correct together.

Questions

1. Which machine is used in power transmission?
2. Is a generator AC or DC? Can it be both?

Activity 4.9 Guest Speaker – Electrical Technician or Engineer

Objective: To give real-world insights into the use of electrical machines.

Materials Needed

- Prepared questions
- Notebook
- Recorder (optional)

Steps

1. Invite a guest speaker from the power or electrical industry.
2. Prepare questions beforehand.
3. During the session, take notes.
4. Afterwards, reflect on key points discussed.

Questions

1. What is the most used machine in your work?
2. Have you faced any issues with machines not functioning?

THE USES OF TRANSFORMERS, DC & AC MOTORS, DC AND AC GENERATORS, AND SPECIAL ELECTRICAL MACHINES (I.E. STEPPER MOTORS, SERVO MOTORS, ETC.)

Transformers

Transformers are devices that move electrical energy from one circuit to another using a magnetic field. They do this without changing the frequency of the electricity.

Types of Transformers

- Step-up Transformer:** Increases voltage. Used to send electricity over long distances.
- Step-down Transformer:** Lowers voltage. Used in homes and electronic devices.
- Isolation Transformer:** Keeps two circuits separate for safety, without changing the voltage.

Examples

- Mobile phone charger:** Uses a step-down transformer to reduce 230V to about 5V.



Figure 4.6: A picture of a step-down transformer for electronic circuits.

- Power stations:** Use step-up transformers to raise voltage for long-distance transmission.

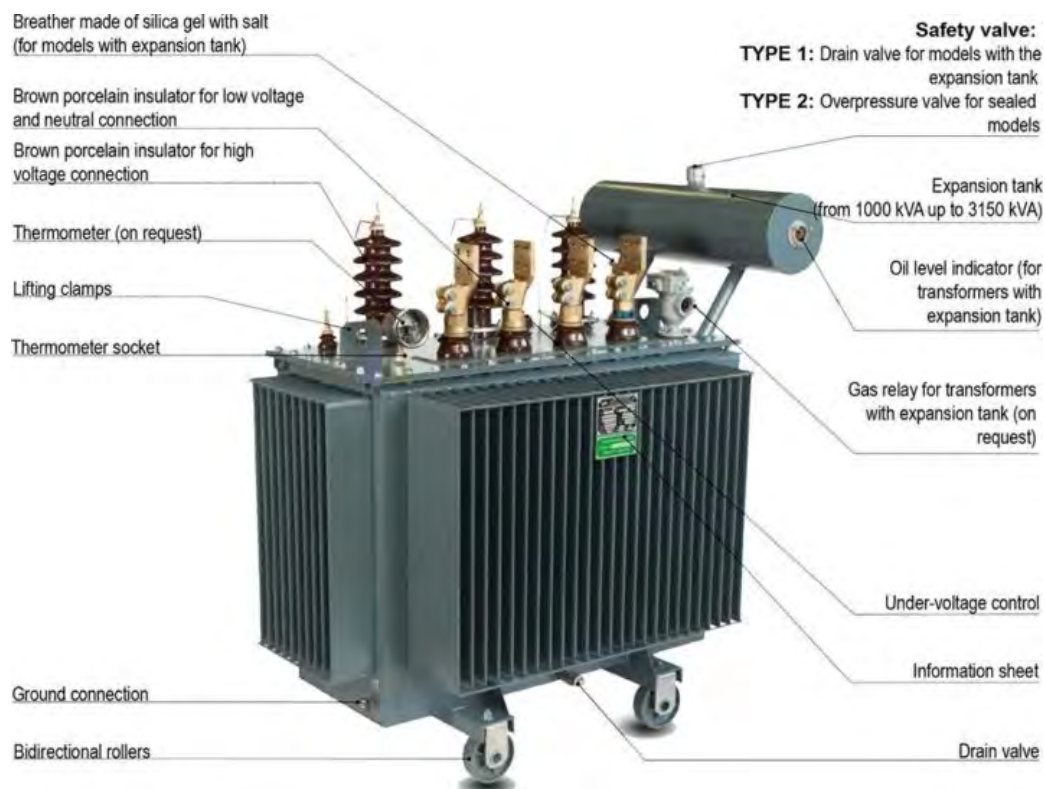


Figure 4.7: Picture of a power transformer.

Uses of Transformers

- a. **Step-up/Step-down Voltage:** Used to increase or decrease voltage for safe and efficient electricity transmission.
- b. **Power Supply Units:** Help devices like TVs and chargers get the correct voltage.
- c. **Isolation:** Keep two circuits separate for safety, such as in hospital machines.

Uses of DC Motors

- i. **Electric Vehicles:** Used to drive cars, scooters, and trains.
- ii. **Cranes and Elevators:** Provide strong force to lift heavy loads.
- iii. **Small Devices:** Found in toys, fans, drills, and tools.
- iv. **Industrial Machines:** Used in lathes and conveyors for speed control.
- v. **Robotics and Automation:** Give accurate speed and power control.

Uses of AC Motors

- i. **Factories:** Run pumps, compressors, and conveyors.
- ii. **Home Appliances:** Found in washing machines, fridges, and air conditioners.
- iii. **HVAC Systems:** Power heating and cooling systems.
- iv. **Heavy Machines:** Used in mills, cranes, and large equipment.

Uses of DC Generators

1. **Battery Charging:** Supply power for charging DC batteries.
2. **Welding Equipment:** Provide electricity for DC welding tools.
3. **Laboratories:** Give steady DC power for experiments.
4. **Electroplating/Electrolysis:** Provide the constant DC needed for chemical processes.
5. **Exciters in Generators:** Supply DC to help large AC generators work.

Uses of AC Generators (Alternators)

1. **Power Stations:** Generate electricity for homes and businesses.
2. **Backup Power:** Used in hospitals and airports during power cuts.
3. **Wind Turbines:** Turn wind into AC electricity.
4. **Vehicles:** Provide electricity in cars and planes.

Uses of Special Electrical Machines

1. **Stepper Motors**
 - a. Used in **3D printers**, **CNC machines**, and **robotics** for very accurate movements.
 - b. Example: Moving the print head in a printer step by step.

2. **Servo Motors:** Used in **robots**, **camera auto-focus**, and **antenna systems** where precise positioning and speed control are needed.

Activity 4.10 Electrical Machines Video

Materials Needed

- Laptop, Projector.
- Notebook or worksheet for jotting down notes.
- Pen or pencil.

Steps

1. Watch a short video on Electrical Machines
2. Scan this QR code or use the link below to watch the video: <https://youtu.be/kXiMQOkado?si=swyeVDN0kxt-jQ6y>



Questions

1. Name two uses of AC machines mentioned in the video.
2. How does the video describe the role of AC motors in everyday systems?
3. Why are AC machines especially useful in industrial or power applications?
4. Can you think of an example at home or in industry where you have seen an AC motor or generator at work?

Activity 4.11 Types of Electric Motors

Materials Needed

- A Laptop and a projector.
- Notebook or worksheet for taking notes.
- Pen or pencil.

Steps

1. **Introduction:** This session focuses on **types of electric motors** and their applications.
2. **Watch the Video**

a. Play the video below

https://youtu.be/ZGGQBPA-v6o?si=2K_3v02xFLBYZ7Vy



b. Note the following

- i. The different motor types are mentioned.
- ii. Highlights about how they work and where they are used.

3. Discussion

Use these prompts to explore your observations

- a. What motor types did you hear? (e.g., brushed DC, brushless DC, AC, synchronous)
- b. For each motor type: how does it work? Where is it used?

4. **Reflection:** Note **one key motor type** and write its function and a practical example.

Questions

1. Identification

- a. List all the motor types explained in the video.
- b. Is a brushless DC motor the same as an AC motor? Explain.

2. Operation & Features

- a. Describe how a brushed DC motor works compared to a brushless motor.
- b. What makes synchronous motors run at fixed speeds?

3. Application

- a. Which motor type is best for small electronics (such as drones)? Why?
- b. Why are AC induction motors commonly used in home appliances?

4. Deeper Thought

If you needed a motor for precise speed control in a robot, which type would you choose? Explain your choice.

OPERATE (CONNECT, CONTROL, AND DISCONNECT) ELECTRICAL MACHINES

1. Connecting Electrical Machines

- a. **Check Machine Ratings:** Make sure the voltage, current, and frequency of the machine match the power source.
- b. **Use Correct Wiring:** Connect the wires properly. For example, connect a motor to a switch or contactor, or connect a transformer to the power supply.
- c. **Install Protection Devices:** Use fuses, circuit breakers, or overload relays to protect the machine from damage.
- d. **Follow Safety Rules:**

Always switch off the power and make sure the system is grounded before connecting wires.

2. Controlling Electrical Machines

- a. **Start and Stop Safely:** Use ON/OFF switches, contactors, or starters to run and stop machines safely.
- b. **Speed Control**
 - i. For **DC motors** – adjust the armature voltage or field current.
 - ii. For **AC motors** – use a Variable Frequency Drive (VFD) to change the speed.
- c. **Direction Control**

Change the direction of rotation by:

- i. Reversing wires in DC motors.
- ii. Swapping two phases in AC motors.
- d. **Monitor the Machine**

Keep an eye on voltage, current, temperature, and speed to make sure the machine is working properly.

3. Disconnecting Electrical Machines

- a. **Switch Off First:** Always turn off the power before removing any connection.
- b. **Use Proper Switches:** Use isolator switches or circuit breakers to disconnect safely.
- c. **Check for Stored Energy:** Make sure any energy stored in components like capacitors has been released.
- d. **Lock and Tag (if needed):** In industrial setups, use Lockout/Tagout (LOTO) procedures to keep the machine off during repairs.

Example: Operating a Motor

- a. **Connect:** Wire the motor to the supply using a contactor and overload protector.

- b. **Control:** Use push buttons to start and stop the motor. Check the current while it runs.
- c. **Disconnect:** Switch off the supply, open the circuit breaker, and disconnect the wires safely.

Activity 4.12 Direct-On-Line Starter System

Materials Needed

- A computer and a projector to view the video.
- Notebook or worksheet for recording observations.
- Pen or pencil.
- Diagram of a basic DOL starter circuit (optional handout).

Steps to Follow

1. **Introduction:** Briefly explain that a DOL starter is a simple method to start AC motors by connecting them directly to the power supply through protective devices and switches.
2. **Watch the Video**

- a. Play the video about DOL starter basics.

https://youtu.be/Gx7krW1c4mw?si=_OxBWc7gvhlWfWyL



- b. *Note*
 - i. Key components shown (e.g., contactor, overload relay, protective devices).
 - ii. The order in which the starter energises and the motor starts.

3. **Sketch & Label**

After watching the video, draw or label a simplified DOL circuit diagram, identifying:

- a. Power supply
- b. Contactor coil and contacts
- c. Overload relay
- d. Start/Stop pushbuttons

e. Motor connection

4. Class Discussion (3 min)

- a. Share;
 - i. How the motor starts when “Start” is pressed.
 - ii. What happens if the motor draws too much current?

Questions

1. Identification

- a. Which components make up the DOL starter circuit?
- b. What does the overload relay do?

2. Sequence

- a. What happens when the “Start” button is pressed?
- b. Describe how the motor stops when the “Stop” button is pressed.

3. Protection & Safety

- a. Why is the overload relay important in protecting the motor?
- b. What could go wrong if the contactor or relay fails?

4. **Application:** Can you think of a practical machine or application where a DOL starter would be a good choice? Explain why.

Activity 4.13 Connecting and Running a Single-Phase Induction Motor

Objective: To connect a single-phase AC motor to a power source and operate it safely.

Materials Needed

1. Single-phase induction motor
2. Capacitor (start/run)
3. Power supply (220V AC)
4. Wires
5. Switch
6. Multimeter
7. Safety gloves and goggles

Steps

1. Ensure power is OFF before beginning.
2. Connect the capacitor between the start and run windings of the motor.
3. Connect live and neutral wires to motor terminals via the switch.
4. Use a multimeter to confirm continuity and proper wiring.
5. Turn ON the switch to start the motor.

6. Observe and record rotation direction.
7. Turn OFF switch and disconnect the power supply.

Questions

1. Why is the capacitor needed in a single-phase motor?
2. What safety steps did you follow before connecting the motor?
3. What happens if the capacitor is not connected?

Activity 4.14 Reversing the Rotation of a DC Motor

Objective: To control the direction of rotation of a DC motor.

Materials Needed

- Small DC motor
- 12V battery or DC power supply
- SPDT switch or toggle switch
- Connecting wires
- Breadboard or terminal block

Steps

1. Connect the motor to the switch terminals.
2. Connect the power supply across the switch.
3. Flip the switch to one side – observe rotation direction.
4. Flip the switch to the other side – observe the reversed direction.
5. Disconnect the power supply and motor safely.

Questions

1. How does changing polarity affect the motor direction?
2. Can you reverse a DC motor without using a switch?
3. What devices use this principle in real life?

Activity 4.15 Start and Stop an AC Motor Using a Contactor and Push Button

Objective: To wire and operate an AC motor using a contactor circuit with push buttons.

Materials Needed

- AC motor (small 3-phase or 1-phase)
- Contactor with auxiliary contacts
- NO (Normally Open) Start push button

- NC (Normally Closed) Stop push button
- Control cables
- Power source (lab-supplied)
- Wiring diagram

Steps

1. Wire the contactor coil through the Start and Stop buttons.
2. Use the auxiliary contact to latch the contactor.
3. Connect the motor to the main contacts of the contactor.
4. Double-check wiring and power off.
5. Turn ON power and press the Start button — the motor should run.
6. Press the Stop button — the motor should stop.
7. Power off and disconnect safely.

Questions

1. What is the function of the auxiliary contact?
2. Why is a stop button normally closed?
3. What would happen if the latch contact wasn't used?

Activity 4.16 Speed Control of a DC Motor Using a Variable Resistor (Rheostat)

Objective: To control the speed of a DC motor using a rheostat.

Materials Needed

- DC motor
- Variable resistor (rheostat)
- 12V DC power supply
- Wires
- Switch

Steps

1. Connect the power supply to the DC motor via the rheostat.
2. Turn ON the switch — the motor starts.
3. Vary the resistance and observe speed changes.
4. Measure voltage across the motor at different resistance levels.
5. Turn OFF switch and disconnect safely.

Questions

1. What is the relationship between resistance and motor speed?
2. Why would you use a rheostat in a control circuit?
3. What are the disadvantages of this speed control method?

Activity 4.17 Operating a Stepper Motor with a Microcontroller (Arduino)

Objective: To connect and control a stepper motor using an Arduino and code.

Materials Needed

- Stepper motor (e.g., 28BYJ-48)
- ULN2003 driver board
- Arduino board (Uno or similar)
- USB cable
- Jumper wires
- Pre-written Arduino sketch/code
- Laptop with Arduino IDE

Steps

1. Connect the stepper motor to the driver board.
2. Connect the driver board to Arduino (IN1–IN4 pins).
3. Upload the sketch to Arduino to rotate the motor forward/backwards.
4. Run code and observe step-by-step motion.
5. Modify code to change speed and direction.
6. Power off and disconnect components.

Questions

1. What type of control signal does a stepper motor need?
2. How does a stepper differ from a DC motor?
3. Why are stepper motors used in printers and CNC machines?

SAFETY MEASURES ASSOCIATED WITH THE USE OF THE VARIOUS ELECTRICAL MACHINES

Electrical machines like transformers, motors (AC and DC), generators, stepper motors, and servo motors are used in homes, offices, and factories. But since they use electricity and moving parts, they can be dangerous if not used properly. Good safety practices help prevent: Electric shocks, Fire hazards, Injuries from moving parts, Damage to machines and Unplanned shutdowns.

General Safety Tips for All Machines

These rules apply to any electrical machine you work with:

1. **Wear Safety Gear (PPE)**
 - a. Use insulated gloves and boots.

- b. Wear safety goggles near sparks or moving parts.
 - c. Use ear protection if the machine is noisy.
- 2. **Lockout/Tagout (LOTO)**
 - a. Turn off the power before maintenance.
 - b. Lock the switch and add a warning tag.
 - c. Only trained staff should unlock it.
- 3. **Use Circuit Protection**
 - a. Install fuses, circuit breakers, and overload relays.
 - b. Use RCDs or ELCBs to protect against leakage current.
- 4. **Proper Grounding (Earthing):** Connect machines to the ground to avoid shocks.
- 5. **Keep the Area Safe**
 - a. Work in a dry, bright, and clean space.
 - b. Ventilate the area to avoid overheating.
 - c. Keep wires tidy and tools in order.

Machine-Specific Safety

- 1. **Transformers**
 - a. Don't overload them.
 - b. Check for oil leaks (if oil-filled).
 - c. Test insulation regularly.
 - d. Install in a dry, ventilated area.
- 2. **Motors (AC & DC)**
 - a. Use overload protection to prevent overheating.
 - b. Choose the right motor starter (like DOL, Star-Delta, or VFD).
 - c. Cover rotating parts.
 - d. Watch for vibrations—they could mean a problem.
- 3. **Generators**
 - a. Turn off and isolate before checking.
 - b. Use an AVR for stable voltage.
 - c. Store fuel safely (for fuel-powered generators).
 - d. Use breakers to prevent power from flowing backwards.
- 4. **Stepper Motors**
 - a. Use drivers that limit current.
 - b. Mount them securely.

- c. Follow voltage and step size ratings.

5. Servo Motors

- a. Calibrate feedback devices like encoders.
- b. Add brakes when lifting loads.
- c. Control speed changes to avoid sudden motion.

Maintenance and Inspection Tips

1. Check machines regularly for wear, noise, heat, or loose parts.
2. Use insulation testers to check coils and windings.
3. Clean off dust, oil, and dirt.
4. Record all checks and repairs.

Training and Supervision

Make sure all workers:

1. Know how to operate machines safely
2. Understand how to shut down in emergencies
3. Can spot warning signs like strange smells, noise, or heat
4. Are supervised if they are new or untrained

Watch Out for These Hazards

Hazard	Risk	How to Prevent It
Exposed wires	Electric shock	Cover and secure all wires
Overheating	Fire, damage	Ventilate and use cooling systems
Unbalanced loads	Mechanical breakdown	Balance the load properly
Poor grounding	Electric shock	Connect to earth properly
Ignoring alarms	Injury or damage	Train users to respond to warnings

Activity 4.18 Safety Precautions while working on Electrical Equipment

Materials Needed

- Device (computer/projector/screen) to show the video from the link: <https://youtu.be/CpHbDOHnoKA>



- Safety checklist handout (PPE, LOTO steps, circuit protection).
- Pen or pencil.

Steps

1. Introduction

- a. Common hazards of electrical work (electric shock, fire, arc flash) will be discussed in a class discussion.
- b. *“Have you ever used locks or tags on machines before?”* will be discussed.

2. Watch the Video

- a. Screen the video **“Safety Precautions While Working on Electrical Equipment”**.
- b. Note each safety measure demonstrated (e.g., PPE, lockout, grounding, disconnection).

3. Guided Discussion with Handout

- a. Safety checklist handouts will be distributed.
- b. Review each safety step.
 - i. Wearing PPE appropriately.
 - ii. Lockout/Tagout procedures.
 - iii. Proper grounding/earthing.
 - iv. Use of circuit breakers and fuses.
 - v. Confirming power is off before work.
- c. Relate to video demonstrations and invite comments or clarifications.

4. Quick Safety Demo

In groups of two, role-play a simplified lockout/tagout sequence:

- a. Isolate power source.
- b. Apply lock and tag.
- c. Confirm power is off.
- d. Remove the lock only after the work is complete.

5. Wrap-Up & Reflection

- a. In your small group, discuss one safety rule you will remember most.

- b. Emphasise the importance of these practices in preventing injury and equipment damage.

Questions

1. Recall

- a. What are two types of PPE shown in the video?
- b. What is the purpose of placing a lock and tag on an electrical switch?

2. Understanding

- a. How does grounding (earthing) prevent electric shock?
- b. Why should you make sure power is switched off before touching equipment?

3. Application

- a. In your school lab, which safety step would you use first before repairing equipment? Explain.
- b. How would you check if the power is truly off after locking out a circuit?

4. Reflection

- a. Why might someone skip safety steps even when they know them?
- b. What personal safety habit will you commit to when working on electrical machines?

Activity 4.19 Lockout/Tagout Safety

Materials Needed

- Laptop, Projector, and Video from the link:
https://youtu.be/HcvJ_Xp-oyo?si=6w9oSlh56pSUdtSP



- Sample padlock and tag for demonstration.

Steps

1. **Introduction:** Explain LOTO as a method to prevent accidental equipment startup during maintenance.
2. **Presentation of the LOTO Steps**
The typical LOTO steps will be presented

- a. Notify affected personnel.
- b. Shutdown equipment.
- c. Isolate all energy sources (electric, hydraulic, pneumatic).
- d. Lock the isolation device with a padlock.
- e. Tag it with a label explaining who locked it and why.
- f. Try to operate the controls to ensure isolation.
- g. Perform maintenance safely.
- h. Remove lock+tag and restore power.

Discuss each step with examples.

3. Demonstration

- a. Using a mock panel or switch.
- b. You will be walked through a LOTO scenario:
 - i. Announce shutdown.
 - ii. Turn off power.
 - iii. Apply lock and tag.
 - iv. Test that power is off (e.g., press a switch).
 - v. Show removing the lock and restoring power.

4. **Practice:** With your partner, conduct a quick LOTO simulation: fill out a tag, lock the switch, test isolation, and briefly explain the process to a partner.

5. Debrief

- a. Review the steps and why each is essential.
- b. Emphasise that only the person who attached the lock should remove it.

Questions

1. Recall

- a. What does “lockout/tagout” mean?
- b. Why must you “try” operating the equipment after locking it?

2. Understand

- a. How does LOTO protect maintenance workers?
- b. What could happen if someone removes a lock they didn’t place?

3. Apply

- a. You must service a fuse panel—what steps would you take to safely lock it out?
- b. Describe what information you’d write on a LOTO tag.

4. Reflect

- a. Why isn't shutting off the power alone enough?
- b. How would you ensure everyone knows maintenance is ongoing?

Activity 4.20 Exploring Electrical Machines and Circuits

Materials Needed

- Chart of electrical machines (transformers, AC/DC motors, generators, stepper & servo motors)
- Real or simulated machines (optional: kits or models)
- Electrical circuit board/training kits
- Assorted components: resistors, capacitors, diodes, transistors
- Safety gloves and goggles
- Multimeters
- Wire and terminals
- Lockout/tagout tags for safety practice

Steps

1. Identification of Machines and Components

- a. See display of real machines or posters of transformers, motors, generators, stepper and servo motors.
- b. Inspect each and record their names, functions, and classifications.
- c. Class discussion on applications of each machine.

2. Use and Operation of Machines

- a. Demonstrate the connection of a transformer and a DC motor using safe voltage.
- b. Connect and run the machines under supervision.
- c. Use a multimeter to monitor voltage, current, and motor rotation.

3. Safety Procedures

- a. Watch a safety video or review posters on lockout/tagout and machine hazards.
- b. Simulate a lockout/tagout procedure in class.
- c. Discuss and list safety measures when working with electrical machines.

4. Circuit Elements and Classification

- a. Examine basic components (resistor, capacitor, diode, transistor).
- b. Sketch each with the correct circuit symbol.
- c. Classify as passive or active elements with reasons.

Questions

1. Recall and Identification

- a. Name three types of electrical machines used in industry.
- b. What is the function of a transformer?

2. Application

- a. How do you reverse the rotation of a DC motor?
- b. Which safety steps must be followed before operating an electrical machine?

3. Classification and Sketching

- a. Sketch the symbol for a capacitor and state if it is passive or active.
- b. Classify a diode and a transistor as either active or passive.

EXTENDED READING

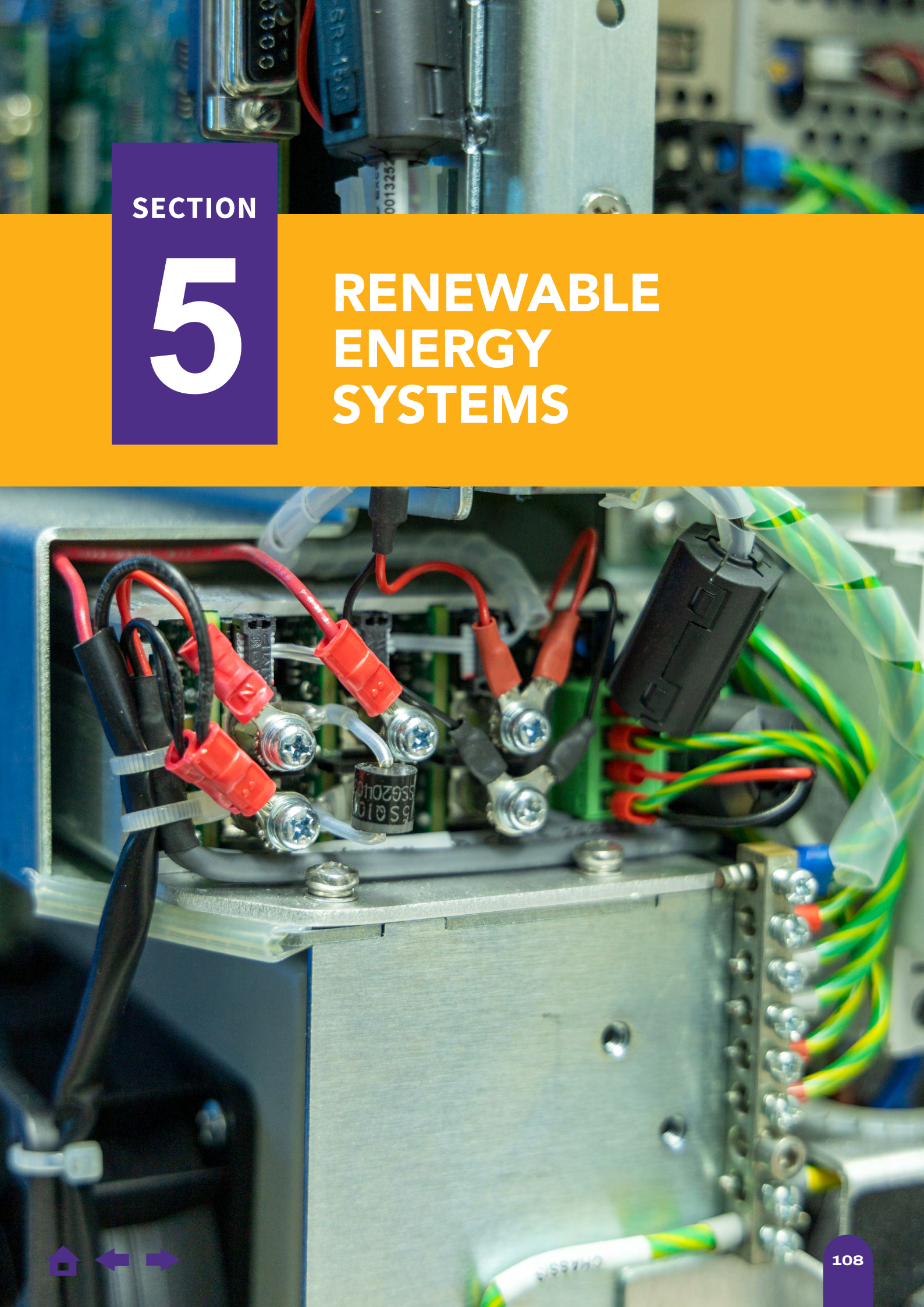
Bandyopadhyay, M. N. (2007). ELECTRICAL MACHINES: THEORY AND PRACTICE. India: PHI Learning.

REVIEW QUESTIONS

1. During a power outage at home, Emmanuel hears his father say, “We should turn on the generator.” What kind of electrical machine is a generator, and what does it do?
2. Akosua plugs her laptop charger into the wall outlet. The charger becomes slightly warm. Which electrical machine is inside the charger, and what is its function?
3. Yaw notices that when the power comes back, the ceiling fan starts spinning. Which electrical machine makes the fan spin, and what energy conversion takes place?
4. Ama builds a small windmill that lights a bulb when she spins the blades. What type of electrical machine is being used here, and what does it do?
5. Kojo controls his toy car using a remote. The wheels move forward and backwards. Which electrical machine is used in the toy car, and what is its function?
6. In the school office, the photocopier makes repeated back-and-forth movements while printing. Which special type of electrical machine might be responsible for this precise movement?
7. Kwabena observes that the school’s automatic gate opens slowly and smoothly. Which electrical machine is likely used in this case?
8. During a factory visit, students observe large machines lifting heavy loads using rotating arms. What kind of electrical machine is likely used in these machines?
9. A technician says the fan’s “motor is burnt.” What does this tell you about the machine inside the fan?
10. Sena connects her phone to a solar-powered power bank. Which two electrical machines are most likely inside the power bank system?
11. At home, Adjoa plugs her phone into a wall socket. The charger reduces the voltage before reaching her phone battery. Explain how a transformer is used in this situation and why it is necessary.
12. During the installation of an air conditioner, the technician explains that it uses a capacitor-start AC motor to drive the compressor. Explain why an AC motor is suitable for this application.
13. When the school experiences a power cut, the backup generator is turned on to supply electricity. Explain the use of the generator in this case and the type most likely used.
14. Yaw starts his motorbike, and the battery begins to charge as he rides. Explain how a DC generator functions in this system.
15. A student notices that the photocopier moves the scanning head smoothly and in tiny steps. Explain which electrical machine is responsible for this movement and why it’s ideal.
16. During a video of a car factory, students observe robotic arms placing parts with high accuracy. Explain the role of servo motors in this robotic application.
17. Kofi adjusts the speed of his ceiling fan using a regulator. Explain how the AC motor in the fan responds to speed control.

18. Students fly a drone that uses small motors to hover and move in different directions. Explain the use of special electrical machines in drones.
19. A student observes a welding machine with a bulky transformer inside. Explain the role of the transformer in welding machines.
20. A 3D printer in the tech lab moves the print head smoothly and places material layer by layer. Explain the use of stepper motors in this 3D printer.
21. Your school installs a ceiling fan. The technician connects it to a switch before turning it on. Why is it important to connect the fan to a switch before powering it on?
22. After using a blender, Abena pulls the plug out of the socket. Is this the correct way to disconnect the machine? Explain.
23. Kwame connects a light bulb to a battery using a switch. He notices the light only turns on when the switch is closed. What part of the setup controls the light, and how?
24. During a power outage, the technician connects a portable generator to the school's lighting system. What should be done before connecting the generator to the load?
25. Before turning on a DC motor, the teacher checks the connections and ensures the power is off. Why must the power be off when connecting an electrical machine?
26. When Kojo connects a fan, nothing happens. He checks and sees that the switch is off. What step did he miss in the operation process?
27. After drilling a hole, Linda wants to unplug the electric drill. What safety measure should she take before unplugging it?
28. Yaw adjusts the fan speed using a regulator knob. What does this action demonstrate about controlling electrical machines?
29. The school bell is connected to a timer switch and rings at specific times. How is the control of the bell managed in this setup?
30. The gardener connects the water pump to a socket and uses a switch to start it. Why is it important to have a switch in the setup of the pump?
31. Emmanuel is using an electric drill in the workshop. He notices the cord is frayed. What should he do before continuing to use the drill, and why?
32. A cleaning assistant places a standing fan on a wet floor. Why is this unsafe, and what safety measure should be followed?
33. During a practical session, the teacher tells students to wear insulated gloves while working with electrical machines. What is the purpose of using insulated gloves?
34. Kojo plugs a transformer and an iron into the same power extension. Why should he avoid this, and what is the safety concern?
35. Ama sees a motor with a damaged plug but wants to use it anyway. What is the risk involved, and what should she do?
36. After using a DC generator, Linda pulls the cord from the wire instead of the plug. Why is this dangerous, and what is the correct method?
37. The electrician connects a green wire to a metal part of an AC motor. What is the purpose of this connection?
38. Joshua begins cleaning inside a motor while it's still plugged in. Why is this unsafe, and what safety step should be followed first?

39. A student notices a ceiling fan making a rattling noise. What should be done before inspecting it, and why?
40. Before connecting a motor, the teacher ensures that the power switch is off. Why is it important to keep the power off before connecting an electrical machine?

The background of the page is a close-up photograph of an electronic device's internal components. It shows a metal chassis with various wires (red, black, green, yellow) connected to terminals and components. A small cylindrical component with the text 'SS6204' is visible. The top half of the page has a purple and orange gradient overlay containing the section title.

SECTION

5

RENEWABLE
ENERGY
SYSTEMS

RENEWABLE ENERGY SYSTEMS

INTRODUCTION

In this section, you will explore two important types of renewable energy systems: wind energy and bioenergy. Wind energy systems use wind turbines to convert the kinetic energy from moving air into electrical energy. These systems provide a clean and sustainable source of electricity and help reduce the use of fossil fuels.

Bioenergy systems make use of organic materials such as wood, animal waste, food scraps, and plant matter to produce useful forms of energy, including heat, electricity, and biofuels. These systems also support effective waste management.

This study will help you understand how each part of a wind or bioenergy system works to produce renewable energy. You will also appreciate the importance of these systems in building a cleaner and more sustainable future.

KEY IDEAS

- **Basic Components of Wind and Bioenergy Systems:** Wind energy systems include parts such as wind turbines, blades, shafts, generators, towers, and control systems. Bioenergy systems consist of components like biomass feedstock, digesters or combustion chambers, gasifiers, generators, and energy storage units.
- **Design and Installation of Simple Systems:** You should apply basic engineering skills to plan and assemble a small-scale wind or bioenergy system. This includes selecting appropriate locations, choosing materials, and following correct installation steps for performance and safety.
- **Functions of Each Component:** Blades capture wind energy and spin the turbine. Generators convert rotational energy into electricity. In bioenergy systems, feedstock provides the fuel, and the digester or combustion chamber converts it into usable energy. Control units regulate energy output and ensure safe operation.
- **Operation and Maintenance:** You will gain hands-on experience in running simple wind turbines or bioenergy setups. Emphasis will be placed on regular inspection, cleaning, safe fuel handling, monitoring power output, and repairing faulty components to ensure efficient performance.

BASIC COMPONENTS OF WIND AND BIOENERGY SYSTEMS

Wind Energy Systems

Wind energy systems are used to turn the movement of air (wind) into electricity. This is done using a device called a wind turbine. These systems are important because they produce clean and renewable energy that does not pollute the environment.

Main Parts of a Wind Energy System

a. Rotor Blades

These are the large blades you see on a wind turbine. They are shaped like aeroplane wings to help catch the wind and create lift. Most wind turbines have three blades to help them work smoothly and efficiently.

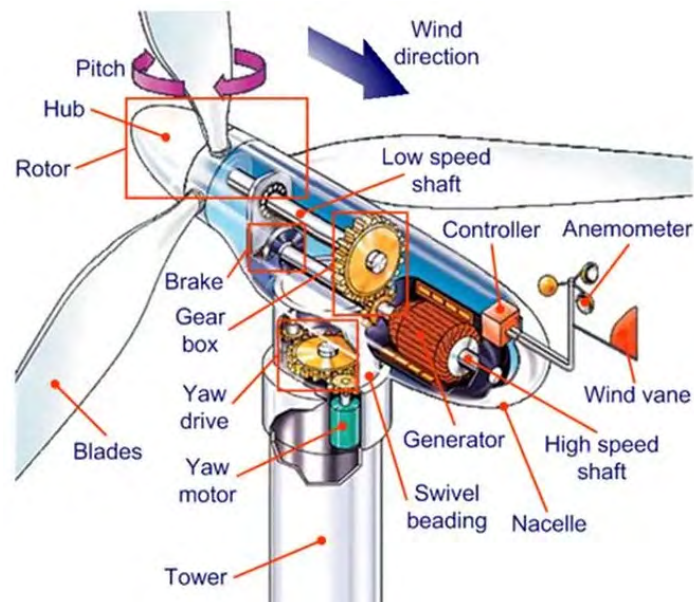


Figure 5.1: Picture of Rotor Blades

b. Hub

Spins with the blades, forming the rotor.

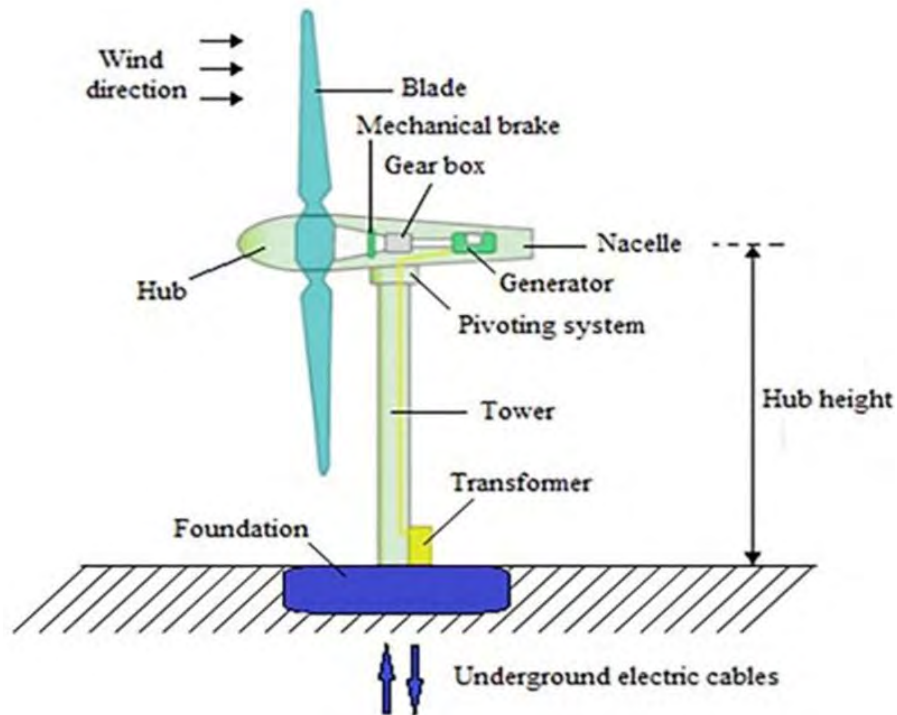


Figure 5.2: Picture of a Hub.

c. Nacelle

The nacelle is the cover at the top of the wind turbine tower.

It protects important parts inside, including:

- i. **Gearbox:** Makes the slow turning of the blades faster so electricity can be produced.
- ii. **Generator:** Changes the turning movement into electrical energy.
- iii. **Brake System:** Stops the blades from spinning when the wind is too strong to keep the turbine safe.

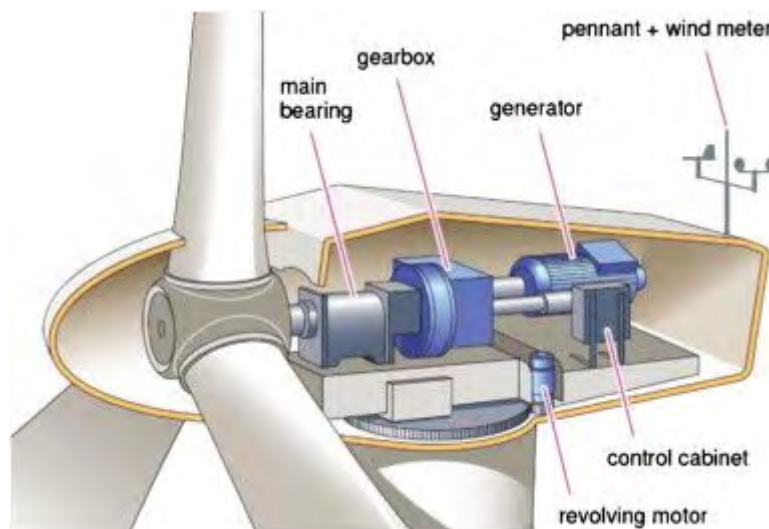


Figure 5.3: Picture of Nacelle

d. Tower

Height allows access to stronger and steadier wind currents.

Made from steel or concrete and anchored into the ground.

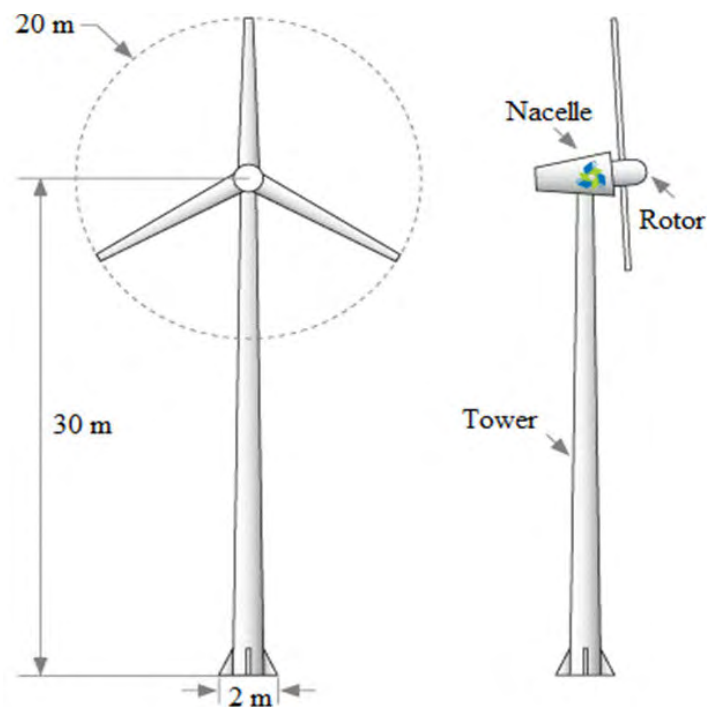


Figure 5.4: Picture of a tower

e. Yaw System

Helps the turbine always catch as much wind as possible.



Figure 5.5: Picture of Yaw system

f. Anemometer and Wind Vane

Anemometer: Measures wind speed.

Wind vane: Measures wind direction.

Feed data to the controller for operational decisions.



Figure 5.6: Picture of Anemometer and Wind Vane

g. Controller

Automatically starts the turbine when wind speeds are within a safe and efficient range.

Shuts down the system during very high winds to prevent damage.

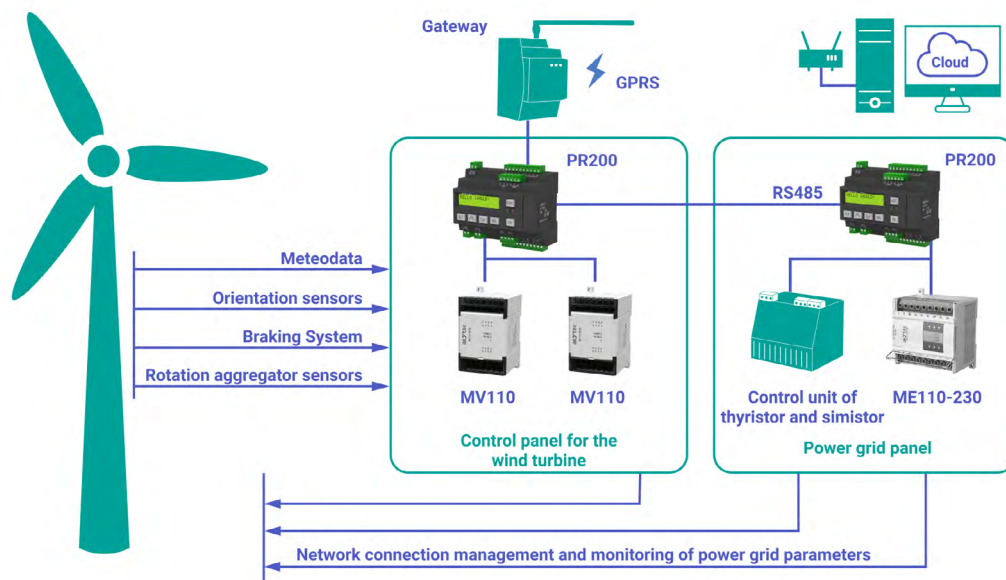


Figure 5.7: Picture of controller. Source:

h. Electrical Cables and Grid Interface

- i. Carry the electrical output from the generator down the tower.
- ii. Connect the turbine to the local grid or storage batteries.

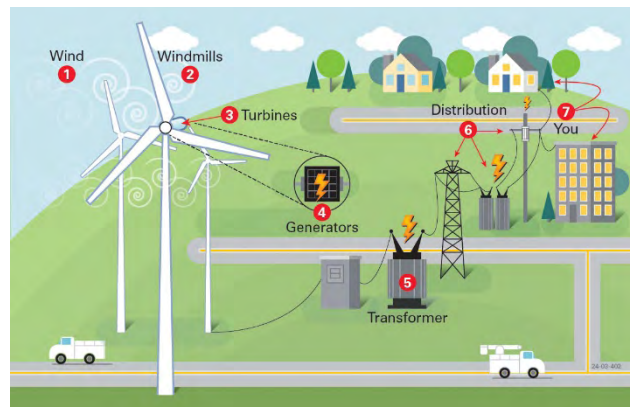


Figure 5.8: Picture of Wind turbine Electrical connections to Grid interface

Bioenergy Systems

Bioenergy systems change natural materials like food scraps, plant waste, animal dung, and wood into useful energy such as electricity, heat, or fuel. These systems help reduce waste and provide a renewable source of energy.

Basic Parts of a Bioenergy System

1. Biomass Feedstock

This is the raw natural material used to make energy.

Types of Biomass

- a. **Solid** – like wood and crop leftovers
- b. **Liquid** – like plant oils and dirty water
- c. **Gas** – like biogas made from methane and carbon dioxide



Figure 5.9: Picture of Biomass Feedstock. Source:

2. Storage System

Holds the feedstock before it enters the processing unit.

Ensures a steady and controlled supply of fuel.



Figure 5.10: Picture of Bioenergy Storage System

3. Feeding Mechanism

Transfers feedstock from storage to the processing or conversion unit.

Can include mechanical conveyors, hoppers, or pumps, depending on the feedstock type.



Figure 5.11: Picture of the Feeding Mechanism of a Bioenergy system

4. Conversion Technology

The process used to transform biomass into energy.

Main types

- Combustion: Burns biomass to produce heat or steam.
- Anaerobic Digestion: Breaks down organic matter in oxygen-free conditions to produce biogas.
- Gasification: Converts biomass into a combustible gas by heating with limited oxygen.
- Pyrolysis: Heats biomass in the absence of oxygen to produce bio-oil and syngas.

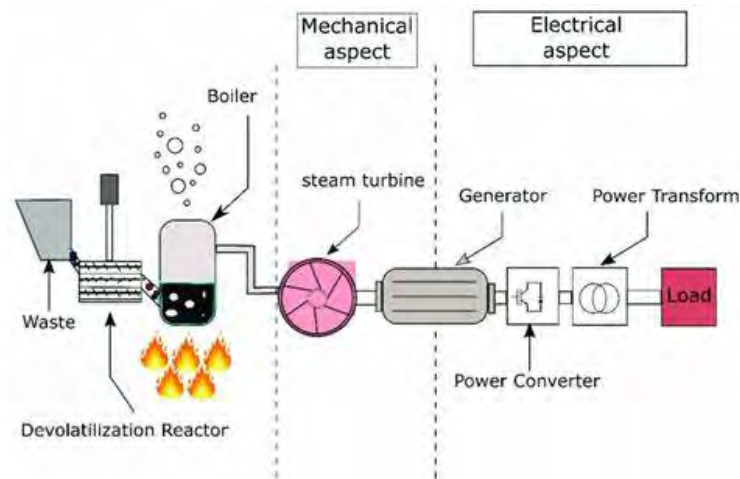


Figure 5.11: Picture of Conversion Technology

5. Reactor / Digester / Combustion Chamber

Where the energy conversion takes place.

Examples

- Digesters for biogas production
- Boilers for steam generation from combustion

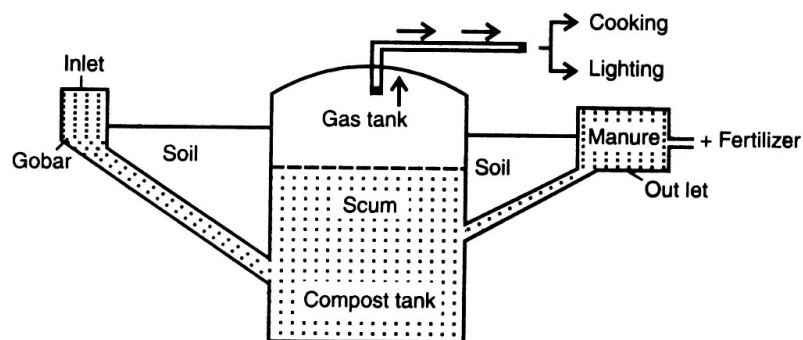


Figure 5.12: Picture of Biogas Combustion Chamber

6. Turbine and Generator (if used for electricity)

- The steam or gas produced from biomass is used to spin a turbine.
- The turbine drives a generator to produce electricity.

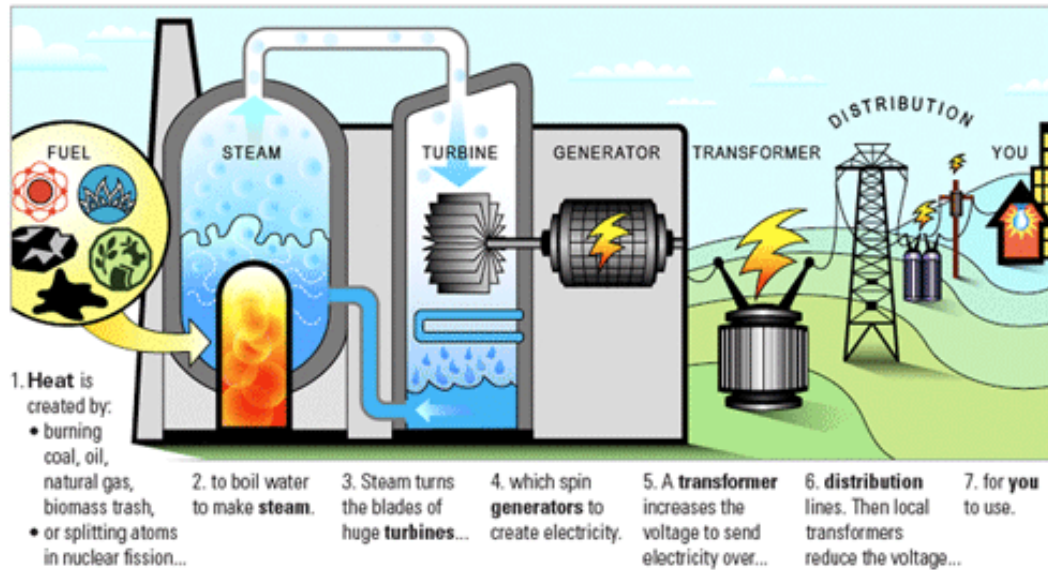


Figure 5.13: Picture of Biogas Steam Generation Station

7. Emission Control Systems

- Filters, scrubbers, or catalytic converters to reduce harmful emissions.
- Ensures compliance with environmental standards.

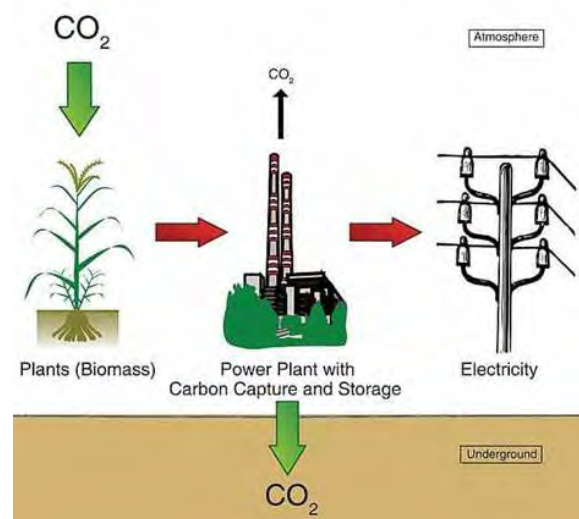


Figure 5.14: Picture of Carbon Capture and Storage Control System

8. Energy Output System

- Distributes the final energy product
- Heat may go to heating systems.
- Electricity can be used locally or sent to the grid.
- Biogas can be stored or converted to electricity.



Figure 5.15: Picture of Biogas Energy Output System

Activity 5.1 Wind Turbine Component Inspection (Model or Real Device)

Objective: To inspect the physical parts of a wind turbine and identify each component's function.

Materials Needed

- Wind turbine model (school-made or commercial kit)
- Diagrams/posters
- Labels and markers

Steps

1. The basic parts: blades, hub, nacelle, generator, shaft, tower, and base will be introduced.
2. Examine a model or parts displayed on a table.
3. Label each part using sticky notes.
4. Discuss each component's function.

Questions

1. What is the function of the nacelle?
2. Why are the blades shaped a certain way?

Activity 5.2 Bioenergy System Component Inspection (Model or Diagram)

Objective: To inspect and identify the main components of a bioenergy (biogas) system.

Materials Needed

- Biogas digester model or cutaway diagram
- Feedstock samples (cow dung, food waste)
- Component tags

Steps

1. Discuss bioenergy and anaerobic digestion.
2. The system components: digester tank, feedstock inlet, gas outlet, gas storage, and slurry outlet will be presented.
3. Observe, identify, and label components.
4. Discuss the flow of materials in the system.

Questions

1. What role does the digester play?
2. What is the function of the gas outlet?

Activity 5.3 Watch a Video on Wind Turbine Installation

Objective: To observe the construction and installation process of a wind energy system.

Materials Needed

- Laptop
- Projector/screen
- Note-taking materials

Steps

1. Watch a wind turbine installation using the video below.

https://www.youtube.com/watch?v=fpmd_br6loI



2. Pause to highlight key components.
3. Take notes and sketch components.
4. Discuss the safety and tools used.

Questions

1. Which component is installed first?
2. How is the turbine anchored?

Activity 5.4 Watch a Video on Biogas Plant Setup

Objective: To understand the sequence of installing a biogas plant and its components.

Materials Needed

- Video access (e.g., Biogas Plant Construction Video)
- Notebooks
- Diagrams

Steps

1. Watch the video on biogas plant setup.
<https://www.youtube.com/watch?v=mCebM7a5XBQ>



2. Identify the tank, inlet, outlet, and pipes.
3. Draw and label the components.
4. Share observations with the class.

Questions

1. What materials are used for construction?
2. How is gas collected?

Activity 5.5 Create a Cardboard Wind Turbine Model

Objective: To build and identify parts of a simple wind turbine using recycled materials.

Materials Needed

- Cardboard

- Scissors, glue
- Small motor
- Plastic bottle
- Fan blades (plastic or cardboard)

Steps

1. You will be guided in cutting and assembling parts.
2. Connect blades to the motor shaft.
3. Mount the turbine vertically.
4. Test using a hairdryer or fan.
5. Label components.

Questions

1. How does wind cause electricity generation?
2. What part rotates?

Activity 5.6 Create a Mini Bio-digester Model

Objective: To observe gas production in a small-scale bioenergy model.

Materials Needed

- 1.5L plastic bottle
- Balloon
- Cow dung or food waste
- Water
- Funnel

Steps

1. Mix organic matter with water.
2. Pour into the bottle and seal with a balloon.
3. Leave in the sun for a few days.
4. Observe balloon inflation.
5. Relate to real biogas system parts.

Questions

1. What caused the balloon to expand?
2. What part would this represent in a real plant?

Activity 5.7 Compare Wind and Bioenergy Components in a Table

Objective: To analyse similarities and differences in wind and bioenergy systems.

Materials Needed

- Comparison chart template
- Textbooks/notes
- Group discussion tools

Steps

1. Fill in a table comparing:
 - a. Energy source
 - b. Key components
 - c. End product
 - d. Storage method
2. Discuss in groups.
3. Present findings.

Questions

1. Which system is better for remote areas?
2. Which has more moving parts?

Activity 5.8 Component Matching Game

Objective: Reinforce component recognition through a game.

Materials Needed

- Flashcards (name on one side, image on the other)
- Timer
- Prizes/stickers

Steps

1. Divide into teams.
2. Show an image—team must say the name and function.
3. Score correct answers.
4. Swap roles.

Questions

1. What is the use of this part?
2. Is this used in wind or bioenergy systems?

Activity 5.9 Presentations

Objective: To research and present on one component of either system.

Materials Needed

- Access to internet/library
- Posters or slides
- Presentation time

Steps

1. You will be assigned a component of a wind or bioenergy system (e.g., rotor, digester).
2. Research the function and design of the component.
3. Create and deliver a short presentation.
4. Class asks follow-up questions.

Questions

1. How does your component improve efficiency?
2. What would happen if it failed?

Activity 5.10 Group Assembly Challenge

Objective: To assemble component cards into a working system diagram.

Materials Needed

- Printed cards with system parts
- Blank board or wall
- Tape

Steps

1. Divide into 2 groups (wind and bioenergy).
2. Hand out shuffled component cards.
3. Arrange in correct order.
4. Explain each component's role.

Questions

1. Why did you arrange it that way?
2. Can you identify any missing parts?

THE FUNCTIONS OF THE BASIC COMPONENTS OF WIND AND BIOENERGY SYSTEMS

This topic focuses on understanding how each **key component** in **wind** and **bioenergy** systems contributes to the generation of renewable energy.

Functions of Basic Components of a Wind Energy System

A wind energy system uses wind to make electricity. It first changes the wind's movement into mechanical energy, then into electrical energy through the turbine.

1. Rotor Blades

Function

Catch the wind and spin around.

Their shape helps lift them, just like aeroplane wings.

This spinning moves the main shaft to create energy.

2. Hub

Function

i. Holds the rotor blades together.

ii. Passes the spinning motion from the blades to the shaft.

iii. Helps keep everything balanced.

3. Nacelle

Function

i. Sits on top of the tower and holds important parts inside, like the gearbox and generator.

ii. Keeps the parts safe from sun, rain, and dust.

iii. Helps turn the spinning movement into electricity.

4. Gearbox (inside the nacelle)

Function

i. Makes the spinning go faster.

ii. This helps the generator work at the speed it needs to make electricity.

5. Generator (inside the nacelle)

Function

Takes the fast spinning from the gearbox and changes it into electricity.

6. Tower

Function

i. Holds up the blades and nacelle high into the air.

ii. The higher it is, the stronger the wind.

iii. Gives strength and support to the turbine.

7. Yaw Mechanism

Function

- i. Turns the top of the turbine (the nacelle) so the blades always face the wind.
- ii. This helps get as much energy as possible.

8. Anemometer and Wind Vane

Anemometer Function: Measures how fast the wind is blowing.

Wind Vane Function: Shows the direction the wind is coming from.

Together, they help decide when the turbine should work or stop.

9. Controller

Function

- i. Watches how the turbine is working.
- ii. Starts the turbine when the wind is strong enough.
- iii. Stops the turbine if the wind is too strong to avoid damage

10. Electrical Cables and Grid Connection

Function

- i. Carry the electricity from the turbine to the ground.
- ii. Send it to batteries, inverters, or the power grid so it can be used.

Functions of Basic Components of a Bioenergy System

A bioenergy system turns natural waste materials like plant parts, food scraps, or animal manure into useful energy—like heat, electricity, or fuel.

1. Biomass Feedstock

Function

- i. This is the raw material (like food waste or wood).
- ii. It holds the energy that will be turned into heat or electricity.

2. Storage System

Function

- i. Keeps the biomass safe and ready for use.
- ii. Makes sure there's always material available when needed.

3. Feeding Mechanism

Function

- i. Moves the biomass from storage into the machine that will turn it into energy.
- ii. Can use things like belts, augers, or pumps.

4. Conversion Unit (based on the method used)**a) Anaerobic Digester****Function**

- i. Breaks down waste without oxygen using bacteria.
- ii. Makes biogas (used as fuel) and a leftover material called digestate (used as fertiliser).

b) Combustion Chamber**Function**

- i. Burns dry biomass to create heat or steam.
- ii. Steam can power machines to make electricity.

c) Gasifier**Function**

- i. Heats biomass with little oxygen to make a gas called syngas.
- ii. Syngas can be used to make electricity.

d) Pyrolysis Unit**Function**

- i. Heats biomass with no oxygen.
- ii. Makes bio-oil, syngas, and charcoal (biochar).

5. Generator or Turbine**Function**

Takes the heat or gas made by the conversion unit and turns it into electricity.

6. Emission Control System**Function**

- i. Cleans the smoke and gas released during burning or gas-making.
- ii. Helps protect the environment.

7. Energy Output Systems**Function**

- i. Sends the energy to where it's needed.
- ii. Electricity can go to homes or be stored in batteries.
- iii. Heat can warm buildings.
- iv. Biogas can be used for cooking or running generators.

Activity 5.11 Watching and Identifying Basic Components of Wind Energy Systems

Objective: To identify and describe the basic components of wind energy systems after watching an instructional video.

Materials Needed

- Projector or computer with speakers
- Video on components of a wind energy system (e.g., turbine blades, rotor, nacelle, generator, tower, controller)
- Notebooks and pens

Steps

1. Introduce the topic and list expected components to be identified.
2. Play the video below once for general understanding.

<https://www.youtube.com/watch?v=jiQ530mxg-U>



3. Play the video a second time; write down each component shown and its function.
4. Join a class discussion where you compare notes with your classmates.
5. On a diagram of a wind system, label the parts.

Questions

1. What are the key components of a wind energy system?
2. What role does the nacelle play in power generation?
3. How do turbine blades contribute to energy conversion?

Activity 5.12 Watching and Identifying Basic Components of Bioenergy Systems

Objective: To observe and identify the main components of bioenergy systems and their functions.

Materials Needed

- Video on components of a bioenergy system (e.g., digester, feedstock, gas holder, burner)

- Worksheet for listing components and writing functions
- Pen/pencil

Steps

1. Receive an introduction to bioenergy and a basic system overview.
2. You will be provided with a worksheet.
3. Play the video below and fill in the worksheet.

<https://www.youtube.com/watch?v=7AlxnCIyHG4>



4. Pause at key moments to discuss functions of specific parts.
5. Join a class discussion where it will be ensured that everyone has accurate information.

Questions

1. What is the role of the digester in a bioenergy system?
2. How is feedstock converted into energy?
3. Which component stores the produced gas?

Activity 5.13 Video Analysis of Wind System Installation Process

Objective: To observe and summarise the key steps involved in installing a wind energy system.

Materials Needed

- Video showing step-by-step installation of a small wind turbine
- Summary chart (Step – Purpose – Equipment used)
- Projector or screen

Steps

1. Receive a briefing to understand installation steps.
2. A summary chart will be handed out.
3. Play the video below while you complete the summary chart.

<https://www.youtube.com/watch?v=c0cUjYBrK5A>



4. Work in pairs to compare and finalise your notes.
5. Join a class discussion on observed safety measures and technical tasks.

Questions

1. What are the major steps in wind system installation?
2. What tools or machines were used during the process?
3. How was safety ensured during installation?

Activity 5.14 Video Analysis of Bioenergy System Installation

Objective: To describe the process of installing a small-scale bioenergy (biogas) system after watching an educational video.

Materials Needed

- Video tutorial of a biogas plant installation
- Observation guide (with columns for step, tool used, purpose)
- Pen/paper

Steps

1. Receive an observation guide.
2. Key terms (e.g., trench, dome, inlet/outlet chamber) will be introduced.
3. Play the video below, pausing after each major step.

<https://www.youtube.com/watch?v=mCebM7a5XBQ>



4. In a small group, complete your guide and share insights.
5. Each group presents one stage of installation to the class.

Questions

1. What materials are required to install a bioenergy system?

2. What is the purpose of each construction step?
3. How is the gas collection system set up?

DESIGN AND INSTALL SIMPLE WIND AND BIOENERGY SYSTEMS

Wind and Bioenergy Systems

Wind and bioenergy systems are two key types of renewable energy technologies. They help produce electricity or heat without using fossil fuels. To design and install simple versions of these systems, you must understand their parts, how they work, and the basic steps to build and maintain them.

1. Simple Wind Energy Systems

Wind energy systems use wind turbines to turn the movement of air into electricity. Small systems can be used at homes, farms, or schools.

a. Basic Design Considerations

- i. **Site Selection:** Choose a place with steady and strong wind (more than 4 m/s).
- ii. **Turbine Size:** Match the turbine power to what is needed (e.g., 400W for lights or small devices).
- iii. **Tower Height:** Taller towers (10–20m) reach better wind speeds.
- iv. **Load Requirements:** Make sure the system matches the amount of electricity needed.

b. Key Components

- i. **Rotor Blades:** Capture the wind's energy.
- ii. **Hub & Nacelle:** Hold the rotating shaft, gearbox, and generator.
- iii. **Gearbox:** Increases rotation speed.
- iv. **Generator:** Changes movement into electrical energy.
- v. **Tower:** Lifts the turbine to catch more wind.
- vi. **Yaw System:** Keeps blades facing the wind.
- vii. **Controller:** Turns the turbine on or off depending on wind speed.
- viii. **Cabling & Inverter:** Sends power to where it's needed and converts it to usable electricity.

c. Installation Steps

- i. Pick a good location and measure wind speed.
- ii. Set up and secure the tower.

- iii. Mount the rotor and nacelle.
- iv. Connect wires from turbine to controller and load.
- v. Link to batteries or grid.
- vi. Test the system to make sure it works safely.

d. Safety and Maintenance

- i. Ground the system and protect from lightning.
- ii. Tie down blades and towers in strong winds.
- iii. Check all parts often for wear or damage.
- iv. Lubricate moving parts to keep them running smoothly.

3. Simple Bioenergy Systems

Bioenergy systems turn organic waste like food, wood, or animal dung into heat, gas, or electricity. They are useful in areas where such materials are available, like farms or rural schools.

a. Basic Design Considerations

- i. **Type of Biomass:** Can be solid (wood), liquid (wastewater), or gas (biogas).
- ii. **Energy Needs:** Decide whether the system will be used for cooking, heating, or electricity.
- iii. **Conversion Method:** Use anaerobic digestion, combustion, or gasification.
- iv. **Output Method:** Connect to a stove, generator, or power grid.

b. Key Components

- i. **Feedstock Storage:** Where the biomass is kept before use.
- ii. **Feeding Mechanism:** Moves material into the system.
- iii. **Conversion Unit:**
 - *Digester* for producing biogas.
 - *Combustion chamber* for burning materials to produce heat.
- iv. **Gas/Heat Collection:** Gathers and transports energy produced.
- v. **Turbine & Generator** (optional): Create electricity from gas or steam.
- vi. **Emission Controls:** Reduce smoke and harmful gases.
- vii. **Distribution System:** Sends energy to where it's needed using pipes or wires.

c. Installation Steps

- i. Choose a location close to the biomass source.
- ii. Set up the digester or combustion unit.
- iii. Install storage and feeding parts.
- iv. Connect gas lines or heat pipes.
- v. Add generator and wires if producing electricity.

- vi. Start the system and measure the output.

d. Safety and Maintenance

- i. Prevent leaks, especially with methane gas.
- ii. Keep the area well-ventilated and at a proper temperature.
- iii. Clean the system often to remove blockages.
- iv. Use filters to reduce smoke.
- v. Check gas pressure and quality regularly.

Activity 5.15 Video Viewing and Discussion on Wind System Operation

Objective: To watch a video and explain how a wind energy system operates from wind capture to electricity generation.

Materials Needed

- Projector or computer
- Video showing wind turbine operation
- Note-taking sheets
- Pens/pencils

Steps

1. The video will be introduced and key terms (wind rotor, gearbox, generator, inverter, grid).
2. Play the video below once for general understanding.
<https://www.youtube.com/watch?v=xy9nj94xvKA>



3. Replay key sections and jot down operational steps.
4. Join a class discussion to clarify processes and roles of components.
5. Join a small group to create a flowchart of the operation.

Questions

1. How is wind converted into electricity in a turbine system?
2. What is the role of the inverter in wind system operation?
3. What happens when there is little or no wind?

Activity 5.16 Research or watch a video and a presentation on Bioenergy System Operation

Objective: To research and explain the operation of bioenergy systems, including feedstock processing and biogas production.

Materials Needed

- Internet access
- Video on the operation of a bioenergy system operation
- Laptops/tablets
- Printed templates for summarising research (What, How, Why)
- Chart paper or presentation software

Steps

1. Join a small group and research the assigned task or watch a video on how a bioenergy system operates.

<https://www.youtube.com/watch?v=5RswjCWaR6I&t=57s>



2. Consider these guiding questions: What materials are used? How is gas produced? How is it stored and used?
3. In your group, summarise findings using the provided template.
4. Prepare a short presentation or infographic.
5. Each group presents their findings to the class in 5 minutes.

Questions

1. What types of feedstocks can be used in bioenergy systems?
2. How does the system convert organic waste into usable energy?
3. How does temperature or environment affect bioenergy production?

Activity 5.17 Video Reflection on Maintenance of Wind Energy Systems

Objective: To identify routine maintenance tasks and safety measures required for wind turbines after watching an instructional video.

Materials Needed

- Maintenance-focused video of wind systems

- Maintenance checklist template
- Pen and paper

Steps

1. You will be provided with a checklist template (e.g., inspect blades, check lubrication, test electrical systems).
2. Play the video below once while you fill in the checklist.
https://www.youtube.com/watch?v=oPhNQ35_Dwo



3. Replay key sections to reinforce understanding.
4. Work in pairs to discuss why each task is important.
5. As a class, discuss the importance of regular maintenance and possible consequences of neglect.

Questions

1. What are three routine maintenance tasks for a wind turbine?
2. What safety precautions should be taken during maintenance?
3. Why is blade inspection important?

Activity 5.18 Research and Role-Play on Bioenergy System Maintenance

Objective: To investigate and role-play the steps involved in maintaining a small-scale bioenergy system.

Materials Needed

- Internet access
- Printed maintenance task cards (cleaning, checking pressure, inspecting valves, etc.)
- Note cards and props (optional)

Steps

1. Join a small group.
2. Your group will be assigned a maintenance task to research (e.g., how to clean the digester, check for leaks, maintain gas pipes).
3. In your group, write down the procedure and materials/tools needed.
4. Prepare a short role-play in your group to demonstrate the task.

5. Each group performs their demonstration to the class.
6. Join a reflection session on which tasks seemed most critical.

Questions

1. What happens if bio-slurry overflows?
2. Why is it important to regularly inspect the gas storage chamber?
3. What personal protective equipment (PPE) should be used?

Activity 5.19 Comparative Report – Operation and Maintenance of Wind vs Bioenergy Systems

Objective: To compare the operation and maintenance of wind and bioenergy systems using video or research and share a brief report.

Materials Needed

- Videos or research resources for both systems
- Comparative worksheet (with sections for operation, maintenance, advantages, challenges)
- Pens, paper, or laptops

Steps

1. You will be provided with a comparison worksheet.
2. You or a pair will be assigned to research or watch videos on both systems.
3. Fill in the worksheet with observations on how each system works and is maintained.
4. Summarise findings in a short oral or written report.
5. You could also volunteer to share your comparisons with the class.

Questions

1. Which system requires more regular maintenance? Why?
2. Which system is more suitable for rural areas and why?
3. What similarities and differences exist in how both systems operate?

OPERATE AND MAINTAIN SIMPLE WIND AND BIOENERGY SYSTEMS

Operating and Maintaining Simple Wind and Bioenergy Systems

Wind and bioenergy systems use natural resources such as wind and biomass to produce electricity or heat. To keep these systems working properly, you must know how to operate them safely and carry out regular maintenance.

Wind Energy Systems

1. Operating a Wind Energy System

a. Before Starting: Safety First

- i. Check the rotor blades for cracks or damage.
- ii. Make sure the tower and base are strong and stable.
- iii. Look over the electrical wires and connections.
- iv. Test the brake system.

b. Starting the System

- i. Use an anemometer to check wind speed (starts working at 3–4 m/s).
- ii. The controller will turn the turbine on when wind speed is good.
- iii. The yaw system turns the blades to face the wind.

c. While It is Running

- i. Wind spins the blades, which turn the generator using a gearbox.
- ii. Electricity is sent to batteries or the power grid.
- iii. The controller watches system performance and keeps it safe.

d. Shutting Down

- i. The system shuts down by itself during very strong winds.
- ii. You can also turn it off using the brake or switch for maintenance.

2. Maintaining a Wind Energy System

a. Daily or Weekly Checks

- i. Look for damage on blades, tower, and cables.
- ii. Listen for strange sounds from the system.
- iii. Check battery levels (if off-grid).

b. Monthly Tasks

- i. Tighten bolts and check supports.
- ii. Clean blades and sensors.
- iii. Test the brakes and disconnects.

c. Yearly Tasks

- i. Oil moving parts like bearings and the yaw system.
- ii. Clean and inspect the generator and controller.
- iii. Run a full system test.

d. Keep Records

- i. Write down wind speeds, power output, and maintenance dates.
- ii. Track parts you replace and problems you fix.

Bioenergy Systems

1. Operating a Bioenergy System

a. Before Starting

- i. Make sure feedstock (like food waste or manure) is ready and clean.
- ii. Check that the digester, pipes, and gas tank are in good condition.
- iii. Look for leaks or broken seals.

b. Starting the System

- i. Put the feedstock into the digester or combustion chamber.
- ii. For biogas systems, keep the temperature between 35–55°C.
- iii. Gas or heat will start forming as the material breaks down.

c. Daily Use

- i. Keep feeding the system with organic material.
- ii. Remove leftover waste (digestate or ash).
- iii. Monitor gas pressure, flame quality, and energy output.

d. Shutting Down

- i. Stop feeding the system.
- ii. Store or release leftover gas safely.
- iii. Clean the system if needed.

2. Maintaining a Bioenergy System

a. Daily or Weekly Tasks

- i. Clean pipes, digesters, and hoppers.
- ii. Check for gas leaks using soap bubbles or gas detectors.

- iii. Clean or replace clogged burners.
- b. Monthly or Seasonal Tasks**
 - i. Empty and clean the digester or burn chamber.
 - ii. Oil pumps and moving parts.
 - iii. Test gas pressure gauges and valves.
- c. Health and Safety**
 - i. Make sure there's fresh air around the system.
 - ii. Use flame arrestors and gas detectors.
 - iii. Wear gloves, face masks, and protective gear when handling waste.
- d. Keep Records**
 - i. Track how much feedstock you add and how much energy is made.
 - ii. Write down any problems or maintenance you do.
 - iii. Record the temperature and gas production levels.

Activity 5.20 Watch Video on Wind Turbine Operation and Maintenance

Objective: To observe and explain how small wind turbines operate and are maintained.

Materials Needed

- Projector or TV
- Video (e.g., How Wind Turbines Work and Are Maintained)
- Notebooks

Steps

1. Wind turbine systems and their operation will be introduced.
2. Play the video below and take notes.

<https://www.youtube.com/watch?v=haPheNEitHQ>



3. Pause to discuss key points (e.g., lubrication, monitoring, faults).
4. Write a summary and share with peers.

Questions

1. What are the key maintenance tasks for wind turbines?
2. What causes most faults in small turbines?

Activity 5.21 Watch Video on Biogas System Operation and Maintenance

Objective: To explore the operation and maintenance of small-scale biogas systems.

Materials Needed

- Video (e.g., How to Maintain a Biogas Plant)
- Whiteboard for notes
- Summary handout

Steps

1. How biogas is produced from organic waste will be explained.
2. Watch the video together.

<https://www.youtube.com/watch?v=Ct3yOcwWShw>



3. Discuss component upkeep (e.g., feedstock quality, clog checks, gas pressure).
4. Create maintenance checklists in a small group.

Questions

1. Why is regular feeding important?
2. What happens if the slurry outlet clogs?

Activity 5.22 Facility Visit (Wind and Bioenergy Systems)

Objective: To interact with professionals and observe real-life systems.

Materials Needed

- Transportation
- Permission forms
- Cameras (optional)
- Question guide

Steps

1. Visit a local facility using wind/biogas systems.
2. Engage with engineers/technicians—ask prepared questions.
3. Observe component operation, safety checks, and tools used.
4. Document what you learned and present key takeaways.

Questions

1. How often do they perform maintenance?
2. What challenges do they face in operation?

Activity 5.23 Operating a Small Wind Turbine Model

Objective: To operate a small wind turbine model and observe energy generation.

Materials Needed

- Wind turbine model
- Multimeter or LED light
- Electric fan (to simulate wind)

Steps

1. Connect turbine wires to the multimeter/LED.
2. Use the fan to simulate wind.
3. Record voltage or light response.
4. Adjust blade angle and measure performance.
5. Discuss efficiency factors.

Questions

1. How does blade angle affect output?
2. What would happen without wind?

Activity 5.24 Operate a Mini Biogas Digester (DIY Setup)

Objective: To observe and measure gas production in a mini digester.

Materials Needed

- 2L bottle
- Food waste/cow dung
- Water
- Balloon
- Funnel

Steps

1. Mix waste with water and pour into the bottle.
2. Seal with a balloon and leave in the sun for 5–7 days.
3. Observe balloon expansion.
4. Measure balloon diameter over time to estimate gas.

Questions

1. What causes the balloon to inflate?
2. What happens if gas is not released?

Activity 5.25 Maintenance Checklist Creation in Groups

Objective: To design checklists for wind and bioenergy system maintenance.

Materials Needed

- Chart paper/markers
- System diagrams
- Maintenance guides (from research or visits)

Steps

1. Divide into two groups: wind and bioenergy.
2. Research maintenance tasks for your group's system.
3. Design colourful, accurate checklists for daily, weekly, and monthly tasks.
4. Display on classroom walls.

Questions

1. Which task is most critical?
2. What tools are needed for maintenance?

Activity 5.26 Group Research and Poster Design

Objective: To research and illustrate system operation with maintenance steps.

Materials Needed

- Internet or textbooks
- Poster paper
- Markers

Steps

1. Join a small group.
2. Each group will be assigned a system (wind or bioenergy).
3. Each group researches operation, components, and maintenance.

4. Draw and label the full system with operational flow and checkpoints.
5. Present and explain to the class in 5 minutes.

Questions

1. What are the signs of system failure?
2. What are the main safety considerations?

Activity 5.27 Design a Wind Energy System for a Facility (Group Work)

Objective: To design a wind energy setup for a school, farm, or clinic.

Materials Needed

- Grid paper or design software
- Sample location specs (wind speed, space)
- Ruler, pencils

Steps

1. Join a small group.
2. A facility scenario with energy needs will be given to your group.
3. In your group design a system: number of turbines, location, wiring.
4. Include component list and operation plan.
5. Present for peer feedback.

Questions

1. How does location affect performance?
2. What components did you include and why?

Activity 5.28 Design a Biogas System for a Community or School

Objective: To design a small biogas plant suitable for local use.

Materials Needed

- Community data (waste generation, cooking needs)
- Design paper
- Markers or CAD tools

Steps

1. In a small group, plan a biogas system: digester size, feedstock type, pipe layout.
2. Identify where each component goes.
3. Explain operation and simple maintenance procedures.
4. Present the plan in class.

Questions

1. What is the expected gas output?
2. How would you train users to operate it?

Activity 5.29 Final Project Presentation and Peer Review

Objective: To present your wind or bioenergy design projects and receive feedback.

Materials Needed

- Design posters or digital slides
- Peer review sheets
- Timer

Steps

1. Join a small group.
2. As a group, present your wind or biogas system designs (from Activities 5.27 & 5.28).
3. Individually fill peer review forms (clarity, feasibility, creativity) for the classmates in your group.
4. Group members provide constructive feedback.
5. The group should reflect on and revise their ideas.

Questions

1. What was the biggest design challenge?
2. How did peer feedback help improve your design?

Activity 5.30 Exploring and Building a Mini Renewable Energy Station

Materials Needed

- Mini wind turbine kit
- Small solar panel
- Biogas/bioenergy model (e.g., plastic bottle digester or simulated system)
- Light bulb or LED
- Wiring, switch, and multimeter
- Diagrams or charts of component functions

Steps

1. Study diagrams and real models of each energy system.
2. Identify components such as rotor blades, generator, PV cells, digester, and heat collectors.

3. In your group, assemble a small station combining a wind turbine, solar panel, and biogas setup to power an LED.
4. Connect systems through a basic circuit and test power output using a multimeter.

Question

How do each of the components in the wind, solar, and bioenergy systems contribute to electricity generation in your mini renewable energy station?

Activity 5.31 Operating and Maintaining Renewable Energy Models

Materials Needed

- Working models of wind turbine, solar panel, and biogas unit
- Maintenance checklist
- Cleaning cloths, lubricant (for moving parts), safety gloves
- Temperature and wind speed meters

Steps

1. Review start-up, operation, and shutdown procedures for each system.
2. Simulate daily operation by observing power output and input levels.
3. Conduct basic maintenance: clean solar panels, inspect turbine blades, check bio-digester for leaks.
4. Record findings in a logbook.

Question

What steps did you follow to ensure each system ran efficiently, and how does the source of energy affect the way it is maintained?

EXTENDED READING

- Ghosh, T. K., Prelas, M. A. (2011). *Energy Resources and Systems: Volume 2: Renewable Resources*. Germany: Springer Netherlands.
- *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change*. (2012). Ukraine: Cambridge University Press.

REVIEW QUESTIONS

1. You are on a school field trip and see a tall structure with three blades spinning at the top. Your teacher asks you: “What is the name of the spinning part that captures the wind?”
2. During a video on wind turbines, a part was shown that changes the direction the blades face when the wind shifts. Your teacher asks: “What is that part called?”
3. A friend is building a model wind turbine for a science project. She asks: “Which part changes the spinning motion into electricity?”
4. At a wind farm, you notice the turbines have a long pole supporting them. The tour guide says it holds everything above the ground. He asks: “Do you know what this part is called?”
5. In your classroom, you are shown a diagram of a wind turbine with a covering that protects the internal parts. Your teacher asks: “What is this cover called?”
6. You are at home, and your parents are composting food waste. You remember learning that similar waste can be used to make energy. Your sibling asks: “What part stores the waste for gas production in a biogas system?”
7. Your class is watching a video on a biogas plant. The presenter says gas moves from the digester to where it is used. Your classmate asks: “What carries the gas to the kitchen or burner?”
8. You visit a rural community and see gas coming from a tank into a cooking stove. The technician explains it’s from animal waste. He asks: “What part of the system collects the gas before it is used?”
9. In class, you learn that leftover slurry from the digester is removed and used as fertiliser. Your teacher points to a pipe at the bottom and asks: “What is this pipe used for?”
10. You and your team are designing a small biogas model. You need to feed food waste into the system and wonder: “What part do we use to add new waste?”
11. During a school visit to a wind farm, the guide points to the blades of a turbine and asks: “Can you explain how the blades contribute to energy generation?”
12. You notice that the turbine blades face the wind direction. Your teacher asks: “Why is it important for the wind turbine to face the wind, and which component helps with this?”
13. In a model demonstration, you observe a housing at the top of the turbine tower. The instructor asks: “Why is the nacelle important in a wind turbine system?”
14. You are asked why wind turbines are so tall. “Can you explain the role of the tower in wind turbine efficiency?”
15. After watching a video on turbine rotation, your classmate asks about the gearbox. “What is the function of the gearbox in a wind turbine?”
16. You visit a biogas plant and see organic waste going into a sealed tank. The technician asks: “Why is the digester a critical part of the system?”

17. A fellow student asks why biogas doesn't leak all over the place. "Can you explain the function of the gas holder?"
18. Your teacher asks what happens to waste materials after digestion. "What is the function of the outlet pipe in a biogas system?"
19. Your group is designing a biogas model and wants to feed kitchen waste into it. "Why is the feeding or inlet tank important?"
20. Your classmate asks what ensures the gas flows to where it's needed. "What is the function of the gas pipeline in a biogas system?"
21. Your school is considering installing a small wind turbine to power its ICT lab. What key factors would you consider when choosing a site for installing the turbine?
22. You are tasked with designing a small wind energy system for a rural health clinic. Why should you include a battery storage system in your design?
23. You are part of a team installing a turbine and are asked to suggest an appropriate tower height. Why is tower height important in wind system design?
24. Your teacher asks what type of wind turbine should be used in low wind speed areas. Which turbine design is more suitable for such locations and why?
25. You are planning the layout for wiring in a wind system setup. Why must proper grounding and safety switches be included during installation?
26. Your class wants to set up a small biogas system for the school canteen. Which types of waste materials would be most suitable as feedstock and why?
27. You are helping design the digester tank for the biogas system. Why must the tank be airtight and made from a durable material?
28. Your team suggests placing the digester in the sunlight. What is the benefit of placing the digester in a warm location?
29. You are presenting your design, and someone asks about the slurry produced. How can the slurry from the biogas plant be used, and why is it beneficial?
30. You are installing the gas pipeline in your biogas system. Why is it important to install valves and check for leaks in the pipeline?
31. Your school's wind turbine has stopped rotating despite a steady breeze. What steps would you take to diagnose the problem?
32. You notice the wind turbine's battery is frequently low, even on windy days. What could be causing this, and how would you resolve it?
33. Your team is assigned to conduct monthly maintenance on a school wind turbine. What are the key components you would inspect, and why?
34. After a storm, the wind turbine is shaking during rotation. What might be the issue, and what should you do?
35. The output from the wind system is erratic. How would you stabilise power output?
36. You observe a drop in biogas production in your school's bio-digester. What could be the cause, and how would you restore production?
37. Gas pressure in the biogas pipeline is low. What might be wrong, and how would you fix it?

38. You are operating the digester and notice foul odours in the area. Is this normal, and how should it be addressed?
39. A team is assigned to remove slurry from the digester. What precautions should be taken during this process?
40. You are monitoring the daily input and output of the bioenergy system. Why is this data important, and how does it help in operation?

SECTION

6

ENERGY EFFICIENCY AND CONSERVATION



ENERGY EFFICIENCY AND CONSERVATION

INTRODUCTION

This section will enable you to develop the skills to design and construct devices for Energy conservation. Energy conservation refers to the use of energy-efficient devices and practices to reduce energy usage. Energy-saving devices help preserve natural resources, cut down on waste, and lower energy costs. You will understand the need to maximise energy use without compromising performance. These gadgets are commonly utilised in homes, workplaces, schools, and industries. Technologies or instruments known as energy conservation devices are made to lower energy usage and boost effectiveness in many contexts. You are witnesses to the rising energy prices, erratic power supplies in some regions, and the requirement for sustainable energy management are all issues Ghana is facing. Therefore, you will be exposed to designing devices that minimise energy waste that can help lessen the strain on the national grid, lower electricity bills, and promote environmental sustainability in households, schools, public institutions, and rural communities. For consumer appliances and lighting, an Energy Management System (EMS) is a collection of devices, software, and techniques used to track, manage, and maximise energy use. You will develop the skill to cut down on energy waste, enhance device performance, and support sustainable energy practices. It combines sensors, controls, actuators, and software.

KEY IDEAS

- **Application Areas for Energy Conservation Devices:** Energy conservation devices are applied in residential settings (e.g., smart lighting, efficient AC units), commercial spaces (e.g., motion sensors, thermostats), industrial operations (e.g., VFDs, energy monitors), and public infrastructure (e.g., solar street lighting, timers)
- **Designing and Constructing Energy Management System Solutions:** You can develop basic energy management systems using microcontrollers to automate lighting and monitor usage, incorporating real-time monitoring, load scheduling, smart controls, and feedback mechanisms for optimisation.
- **Devices Used for Energy Conservation:** Common energy-saving devices such as LED lighting, motion sensors, smart plugs, and energy-efficient appliances are designed to reduce energy wastage and enhance overall system performance.
- **Methodology for Designing Energy Conservation Devices:** The design process for energy conservation involves auditing energy use, selecting efficient components, creating and prototyping a system using tools like Arduino or CAD, and evaluating its effectiveness using measurable criteria.

DESCRIBE DEVICES USED FOR ENERGY CONSERVATION

Energy conservation means using less energy by choosing smart technologies and good habits. This helps lower electricity bills, reduce waste, and protect the environment. Many places like homes, schools, offices, and factories use energy-saving devices to use power wisely without affecting how things work.

Types of Energy-Saving Devices

Lighting systems

LED Bulbs (Light Emitting Diodes)

Function: Use much less electricity and last longer than old-style bulbs.

Energy Savings: Use up to 80% less power than traditional bulbs.

Practical Example: A school replaces classroom lights with LED bulbs and saves money on electricity throughout the term.



Figure 6.1: Picture of LED bulb. Source:

Motion and Occupancy Sensors

Function: Turn lights on when someone enters a room and turn them off when no one is there.

Energy Savings: They stop lights from staying on when not needed.

Practical Example: In an office, sensors are placed in restrooms and hallways, so lights automatically switch off after 5 minutes if no one is around.



Figure 6.2: Picture of Motion and Occupancy sensors. Source:

Daylight Sensors

Function: Adjust artificial lighting depending on how much sunlight is in the room.

Practical Example: In a modern library, lights near the windows automatically dim during bright sunny days.



Figure 6.3: Picture of daylight sensor

Heating, Ventilation, and Air Conditioning (HVAC)

Programmable Thermostats

Function: Let users set temperature schedules based on when spaces are used.

Energy Savings: Reduces heating or cooling when rooms are empty.

Practical Example: A home thermostat lowers the temperature at night and increases it in the morning.



Figure 6.4: Picture of a Programmable Thermostat. Source:

Smart Thermostats

Function: Learn the user's habits and make automatic changes to save energy.

Practical Example: In an office, the smart thermostat lowers AC usage during weekends when no one is around.



Figure 6.5: Picture of Smart Thermostat

Ceiling Fans with Timers

Function: Help air circulate and turn off after a set time.

Practical Example: In a classroom, the fan runs for a set period and then turns off to save electricity.



Figure 6.6: Picture of Ceiling Fan with Timer

Appliance and Device Controls

Smart Plugs and Power Strips

Function: Let users' control and schedule devices remotely.

Energy Savings: Stops devices from using energy when not in use (phantom loads).

Practical Example: A smart plug turns off a projector after 6 p.m. if it hasn't been turned off manually.



Figure 6.7: Picture of a Smart Plug in a socket

Advanced Power Strips

Function: Turn off related devices when the main device is switched off.

Practical Example: In a computer lab, monitors and printers shut down when the computer is turned off.

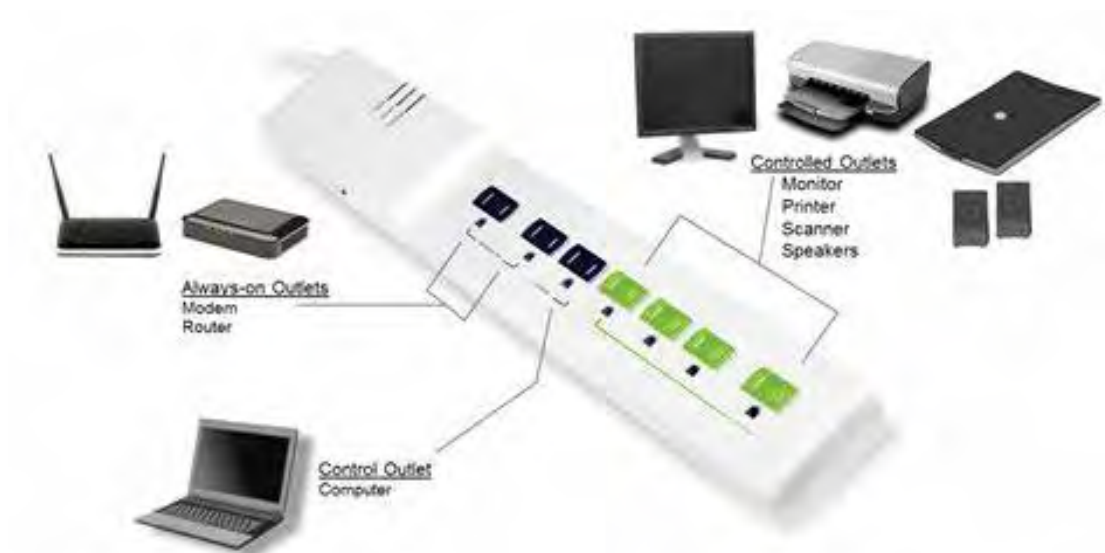


Figure 6.8: Picture of Advanced Power Strips

Energy-Efficient Appliances (e.g., ENERGY STAR)

Function: Use less energy due to better design.

Practical Example: ENERGY STAR fridges in a school kitchen use 40% less electricity than older ones.



Figure 6.9: Picture of Energy-Efficient Appliances

Renewable Energy and Passive Systems

Solar Water Heaters

Function: Use sunlight to heat water.

Practical Example: A boarding school heats water for showers using solar heaters.



Figure 6.10: Picture of Solar Water Heaters

Solar Outdoor Lighting

Function: Use solar panels to power outdoor lights at night.

Practical Example: Lights along school walkways work at night without using electricity from the grid.



Figure 6.11: Picture of Solar Outdoor Lighting

Building Insulation and Double-Glazed Windows

Function: Help keep indoor temperatures stable by reducing heat loss or gain.

Practical Example: An office adds insulation to walls and ceilings to stay cooler during hot days and warmer in cold weather.



Figure 6.12: Picture of Double-Glazed Windows

Industrial and Facility Energy Optimisation

Variable Frequency Drives (VFDs)

Function: Change the speed of motors depending on how much work they need to do.

Practical Example: A fan in a workshop slows down when fewer machines are running.



Figure 6.13: Picture of Variable Frequency Drives

Power Factor Correction Devices

Function: Improve how electricity is used in large systems, reducing energy waste.

Practical Example: A technical school installs capacitors to reduce energy losses in its machine lab



Figure 6.14: Picture of Power Factor Correction Device

Energy Management Systems (EMS)

Function: Track and control energy use in big buildings or campuses.

Practical Example: A university uses EMS to monitor lighting, air conditioning, and lab equipment energy use in real time.

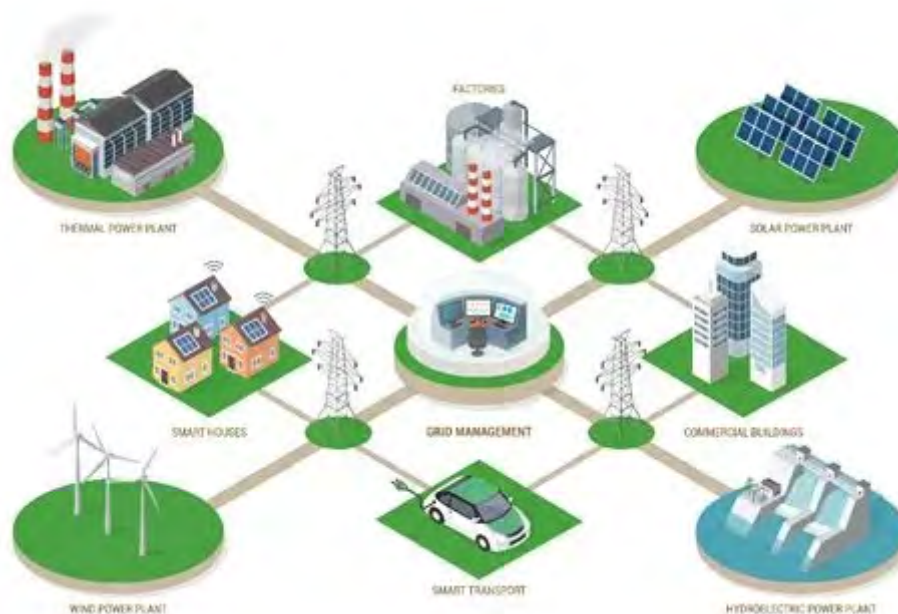


Figure 6.15: Picture of an Energy Management System³

Activity 6.1 Energy Detective - Device Identification Game

To identify and research energy-saving devices, explain their uses and conservation benefits, present the findings, and evaluate the most effective device through class discussion and justification.

Steps

1. Join a small group.
2. Show images of various energy-saving devices such as photocells, motion sensors, dimmers, etc.
3. Each group select three devices, researches them, and writes down their names, uses, and how they conserve energy.
4. Groups present their findings to the class in 5 minutes.
5. Class votes on the most effective device and justifies the choice.

Questions

1. What is the main function of the device you studied?
2. How does this device help conserve energy?
3. Where is this device commonly used?

Activity 6.2 Watch & Reflect - Device Demonstration Video

Observe how energy conservation devices work in real settings.

Steps

1. Watch the video as a class.

<https://youtu.be/NyOx3f7gL8Y?si=bkHMlR3z-92sWYLV>



2. Take notes on the types of devices and how they operate.
3. In pairs, discuss which device you think is most useful and why.
4. Complete a worksheet summarising key points.

Questions

1. What did you observe about how each device functions?
2. Which device do you think is most suitable for home use? Why?
3. How could you apply any of these in your own school?

These next Activities are Optional Extra activities (6.3-6.10)

Activity 6.3 Role Play - “Sell Your Device!”

Demonstrate your understanding of a device by role-playing as sales representatives.

Steps

1. Each group will be given a device (e.g., smart thermostat, occupancy sensor).
2. Groups prepare a 2-minute pitch to “sell” the device to the school.
3. Present pitches to the class.
4. Class votes on which device to “buy” for energy conservation.

Questions

1. What makes your device effective for conserving energy?
2. How would you convince others to use it at school or home?
3. What are the costs and benefits of your device?

Activity 6.4 Compare and Contrast - Traditional vs. Smart Devices

Compare traditional energy-consuming devices with energy-saving alternatives.

Steps

1. Present device pairs, e.g., incandescent bulb vs. LED bulb, regular switch vs. motion sensor.
2. In groups, compare them in terms of energy use, cost, and convenience.
3. Complete the worksheet.
4. Share insights with the class.

Questions

1. What are the key differences between the devices?
2. Which one would you choose and why?
3. Can traditional devices be upgraded for efficiency?

Activity 6.5 Energy Audit Simulation

Identify energy conservation opportunities in a simulated environment.

Steps

1. A sample floor plan will be provided.
2. Suggest areas to install energy-saving devices such as dimmers, motion sensors, etc.
3. Mark placements and justify choices.
4. Present the plan to the class.

Questions

1. Where would you place each device and why?
2. Which devices would offer the most savings?
3. How does the environment affect your device choices?

Activity 6.6 Guest Expert Talk / Interview

Learn from an expert how energy conservation devices are applied in real-world settings.

Steps

1. Prepare 5–10 questions in groups before the guest arrives.
2. Conduct a live interview or watch a pre-recorded one of a guest speaker.
3. Take notes and discuss responses in groups.

4. Share key takeaways with the class.

Questions

1. What are the most used devices for energy conservation?
2. What challenges are faced when using these devices?
3. What advice would the expert give to new users?

Activity 6.7 Case Study - Energy Wastage Problem

Analyse a real-life energy-wasting scenario and propose a solution using conservation devices.

Steps

1. Read and analyse the case (e.g., a school with high electricity bills).
2. Identify problems in energy usage.
3. Propose at least 3 devices that would reduce energy waste.
4. Present findings.

Questions

1. What are the causes of energy waste in this scenario?
2. Which devices can solve these problems?
3. How would the solution impact cost and efficiency?

Activity 6.8 Poster Design - “My Favourite Energy Device”

Design a poster showing how your favourite energy-saving device works.

Steps

1. Choose an energy-saving device individually or in pairs.
2. Research how it works and its advantages.
3. Design a creative and informative poster.
4. Display posters in class and explain them.

Questions

1. What is special about your chosen device?
2. How does it conserve energy?
3. Where is this device most effective?

Activity 6.9 Device Installation Demonstration (Mock Setup)

Understand how devices like motion sensors or dimmers are installed and function.

Steps

1. Demonstrate how a motion sensor or dimmer is connected.
2. Observe and take notes.
3. In pairs, explain the setup to each other.
4. Discuss safety and energy benefits.

Questions

1. What precautions are necessary during installation?
2. How does this setup improve energy efficiency?
3. Could you replicate this at home?

Activity 6.10 Quiz and Debate - “Which Device Saves More?”

Recall and debate which devices offer better energy savings based on usage.

Steps

1. Conduct a short quiz on different devices and their uses.
2. Divide the class into two sides for a debate (e.g., timer switch vs. occupancy sensor).
3. Prepare arguments using prior knowledge.
4. Conduct the debate and reflect.

Questions

1. Which device is more suitable for public places? Why?
2. What factors affect a device’s efficiency?
3. Could combining devices increase energy conservation?

THE APPLICATION AREAS FOR THE VARIOUS DEVICES USED FOR ENERGY CONSERVATION

Energy conservation devices are tools or technologies that help reduce how much energy we use. They are used at home, in schools, offices, factories, and even on the streets. These devices help save electricity, reduce bills, and protect the environment.

1. LED Lighting

LEDs (Light Emitting Diodes) are highly energy-efficient light sources that use a fraction of the electricity consumed by traditional incandescent or fluorescent bulbs.

LEDs are modern light bulbs that use very little electricity and last much longer than old-style bulbs.

Application Areas

- a. Homes: Indoor and outdoor lighting
- b. Schools: Classrooms and hallways
- c. Roads: Street lighting
- d. Offices and Shops

Benefits: They save up to 80% energy and reduce how often bulbs need to be replaced.

2. Smart Thermostats

Smart thermostats control heaters and air conditioners by learning your habits and adjusting temperatures automatically.

Application Areas

- a. Homes
- b. Offices
- c. Hotels

Benefits: They save energy when rooms are empty and can be controlled remotely with a phone.

3. Occupancy and Motion Sensors

These sensors turn lights or fans on when someone enters a room and off when no one is there.

Application Areas

- a. Classrooms, libraries
- b. Restrooms
- c. Corridors and storage areas

Benefits: They prevent lights from being left on unnecessarily.

4. Advanced Power Strips (APS)

APS stops power from flowing to electronics like TVs or computers when they're not in use.

Application Areas

- a. Homes: TVs, sound systems
- b. Offices: Computers, printers
- c. Schools: ICT labs

Benefits: They prevent energy waste from devices left on standby.

5. Energy-Efficient Appliances (e.g., Energy Star Rated)

These are appliances with energy-saving labels (like ENERGY STAR) that use less electricity.

Application Areas

- a. Kitchens: Fridges, microwaves
- b. Laundry: Washing machines
- c. Offices: Coffee makers

Benefits: They reduce electricity bills while working just as well as regular appliances.

6. Solar Water Heaters

These heaters use sunlight to heat water instead of electricity or gas.

Application Areas

- a. Homes
- b. Hotels
- c. Hospitals

Benefits: They lower energy bills and are good for the environment.

7. Variable Frequency Drives (VFDs)

VFDs control motor speeds so machines only use as much power as needed.

Application Areas

- a. Factories
- b. HVAC systems
- c. Water plants

Benefits: They save energy and reduce machine wear.

8. Energy Management Systems (EMS)

EMS are computer systems that monitor and manage energy use in buildings or factories.

Application Areas

- a. Universities and schools
- b. Factories
- c. Malls and big buildings

Benefits: They help track energy use and find ways to save more.

9. Daylight Sensors (Photocells)

These sensors measure daylight and adjust artificial lights to save energy.

Application Areas

- a. Offices and classrooms
- b. Shopping centres
- c. Outdoor lights and parking areas

Benefits: They turn off lights when there's enough sunlight, saving electricity.

10. Insulation Materials and Double-Glazed Windows

These materials keep buildings warmer in cold weather and cooler in hot weather.

Application Areas

- a. Homes
- b. Schools
- c. Offices

Benefits: They reduce the need for fans or heaters and improve indoor comfort.

Activity 6.11 Watch and Tell – Energy Devices in Action

Identify where different energy-saving devices are used in real life.

Steps

1. Watch a video on energy-saving devices using the links below.
 - <https://www.youtube.com/watch?v=vcsINpvD27k>
 - <https://www.youtube.com/watch?v=HkHozg0ckWY>
2. As you watch, list each device and where it is used (home, office, street, etc.).
3. Share your list with your group and compare answers.
4. Each group presents 2 devices and their application areas to the class.

Questions

1. Where was the photocell used in the video?
2. What is the main place where timer switches are useful?
3. How do these devices make our lives easier?

Activity 6.12 Energy Device Detective - School Tour

Explore and identify energy-saving devices around your school and where they are used.

Steps

1. In pairs, walk around the school looking for devices like LED bulbs, motion sensors, or power strips.

2. Note where they are used and why they might be used there.
3. Return and fill out a worksheet about the devices and their application areas.
4. Share your findings in a group.

Questions

1. Which areas of the school use energy-saving devices the most?
2. Why do you think they were installed there?
3. What other areas could benefit from these devices?

Activity 6.13 Match It – Device and Location Card Game

Correctly match energy conservation devices to their appropriate application areas.

Steps

1. Work in groups of 3.
2. Use a set of cards: 1 set with devices (e.g., photocell, dimmer) and 1 set with places (e.g., streetlight, bedroom)
3. Shuffle the cards and take turns matching a device with its ideal location.
4. Each correct match must be explained.
5. The team with the most correct matches wins.

Questions

1. Why is a motion sensor good for a bathroom or hallway?
2. Would you use a photocell indoors? Why or why not?

These next Activities are Optional Extra activities (6.14-6.20)

Activity 6.14 Role Play – The Energy Expert

Explain where and why energy-saving devices are used through role play.

Steps

1. Each group picks a device card containing devices such as a dimmer and a smart plug.
2. Prepare a short role play: one student acts as an expert and the others as customers.
3. Explain where the device can be used and how it saves energy.
4. Perform for the class.

Questions

1. How did your device help solve a problem?
2. Where is it best used?
3. Was it easy to explain?

Activity 6.15 Watch & Compare – Devices at Home vs. Office

Compare energy-saving devices used at home and in workplaces.

Steps

1. Watch the two videos in class.

<https://youtu.be/4jri9K6veHU?si=b27T-K5Zpupzvo5i>



<https://youtu.be/64F3kjb9g78?si=yFCA1S1f0M8hauHt>



2. Fill in a chart listing devices used in homes and those in offices.
3. Discuss: Are any devices used in both places?

Questions

1. Which devices were common to both settings?
2. Why are occupancy sensors more common in offices?

Activity 6.16 Case Study – Saving Energy at a Hotel

Suggest energy-saving devices for specific locations in a hotel.

Steps

1. Read the hotel case study in groups.
2. Discuss which devices can be used in each area, such as the lobby, bathrooms, and rooms.
3. Complete the worksheet and present your plan.

Questions

1. Which device is best for the hotel bathrooms?
2. How can dimmers help in hotel rooms?

Activity 6.17 Design Challenge – “My Energy-Smart Classroom”

Design a classroom using appropriate energy-saving devices.

Steps

1. Use the blank layout to plan an energy-smart classroom.
2. Cut-out drawings of devices (e.g., occupancy sensor, dimmer).
3. Use Glue, scissors, and crayons.
4. Choose at least 3 energy-saving devices and place them in appropriate spots.
5. Explain your choices to the class.

Questions

1. Why did you put a motion sensor at the entrance?
2. What other areas in your school need such devices?

Activity 6.18 Watch and Discuss – Street Energy Devices

Explain how energy-saving devices are used in public spaces like streets.

Steps

1. Watch the video.

<https://youtu.be/kiNxjFDDGCK?si=5zfREHq3iMcvJcok>



2. In small groups, list devices used (e.g., photocells, timers).
3. Discuss the benefits of using these devices in public areas.
4. Share group ideas with the class.

Questions

1. What does a photocell do on a streetlight?
2. How do smart timers help reduce energy at night?

Activity 6.19 Interview at Home – Ask About Energy Devices

Investigate energy-saving devices used in students' homes.

Steps

1. At home, ask parents or guardians what energy-saving devices are used (e.g., LED bulbs, power strips).
2. Fill out your interview sheet with device names and locations.
3. In class, share findings in groups.

Questions

1. What devices were used at home?
2. In which rooms were they found?
3. What new device would you suggest adding?

Activity 6.20 Energy Device Quiz Show

Review and reinforce the application areas of various energy-saving devices.

Steps

1. Form two teams.
2. Take turns answering questions like:
3. “Where would you install a motion sensor?”
4. “Which device is best for outdoor lighting?”
5. The first team to 10 points wins.

Questions

1. Where would you install a photocell?
2. Why are dimmers useful in classrooms?
3. What energy-saving device is best for a corridor?

THE METHODOLOGY FOR DESIGNING DEVICES FOR ENERGY CONSERVATION

Ghana is experiencing increasing electricity costs and power supply challenges in some areas. This makes energy conservation important for everyone, whether at home, in school, or in the community. Designing simple devices that help reduce energy waste can: Help lower electricity bills, reduce pressure on the national power supply, and support the protection of the environment

How to Design Energy-Saving Devices

Creating devices that save energy requires a clear step-by-step plan. Below is a guide you can follow.

1. Identify the Problem or Where Energy is Wasted

Begin by looking for places or situations where energy is not being used wisely. You can do this by:

- a. Observing how electricity is used
- b. Talking to users such as teachers or family members
- c. Doing a basic energy check

Example: At a school in Kumasi, students noticed that classroom lights and fans stayed on even when the classrooms were empty during break time.

2. Define the Design Requirements and Constraints

Decide what your energy-saving device should do and what challenges may affect the design. These may include:

- a. The cost of materials
- b. How easy it is to find materials nearby
- c. The skills of the people who will use the device
- d. Environmental conditions such as heat, dust, or humidity

Example: Create a device that turns off lights and fans in classrooms after ten minutes without any movement.

3. Research and Select Suitable Components

Find out what parts the device needs. The best components are affordable, easy to find in the local market, and simple to use and replace.

Suggested parts include

- a. A motion sensor to detect people
- b. A microcontroller like an Arduino Uno or a simple timer circuit
- c. A relay to switch the fan or light
- d. A battery or connection to the electric power source

4. Design the Circuit and Test It Using Software

Draw the circuit using computer software. Then test the design virtually before building it. If you are using a microcontroller, you may need to write and upload code.

Example: Students use Proteus to draw and simulate the circuit. The sensor detects motion and turns off the fan and light when the room is empty. The code is written using the Arduino IDE and uploaded on the computer in the school lab.

5. Build and Try Out the Device

Put the parts together using a breadboard or a circuit board. Then install and test the device in a real space, such as a classroom or an office. Ask people for their opinions on how well it works.

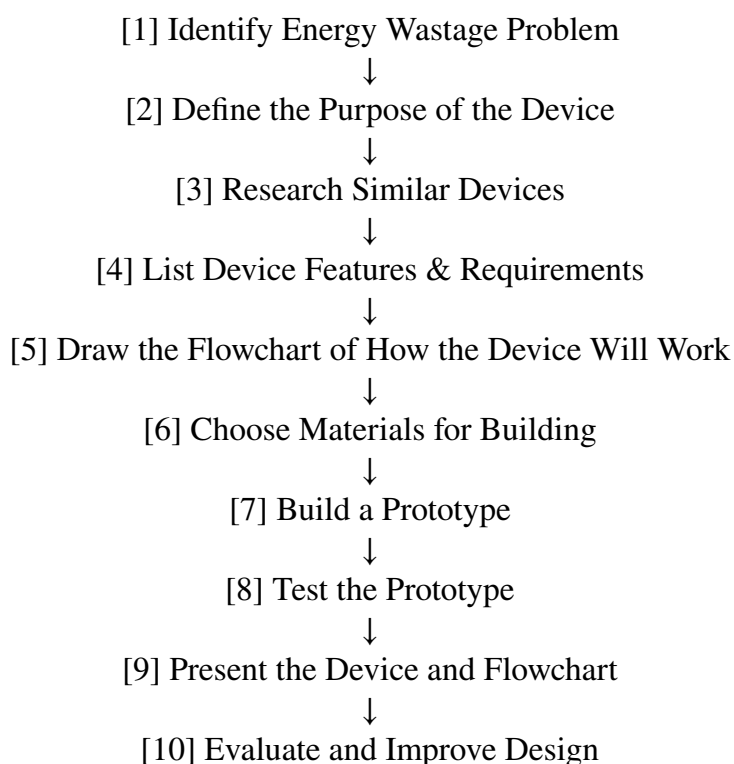
Example: The device is tested in a senior high school classroom. Teachers say it reminds students to conserve energy, and the headmaster notices a small decrease in electricity usage.

6. Review, Improve, and Write About Your Work

Look at how the device performed. Fix any issues, improve the design, and write down the steps taken and what was learned.

Example: After one week of use, students realised the motion sensor did not detect seated people properly. They added another type of sensor that works better and recorded the change in their project report.

Overview Flowchart: Designing Devices for Energy Conservation



Each activity focuses on one part of this process and shows you **how to use a flowchart to represent and guide** that step.

Activity 6.21 Spot the Problem – Where Are We Wasting Energy?

Help you identify real energy problems to solve with a device.

Steps

1. Walk around school or home and note places where energy is wasted (e.g., fans left running).
2. Choose one problem to solve with a device.
3. Draw the first box of your flowchart: “Start → Observe energy wastage in the environment”

Questions

1. What was the biggest waste of energy you found?
2. Could a simple device solve this?

Activity 6.22 Define What the Device Should Do

Write a clear purpose for your device using a flowchart format.

Steps

1. Based on the problem you found, decide what your device should do.
2. Add the next flowchart box: “Define goal → Example: Turn off light when room is empty”

Questions

1. What’s the main goal of your device?
2. Is it simple and clear?

Activity 6.23 Research What Others Have Done

Learn from existing energy-saving devices and update your flowchart.

Steps

1. Search for 2–3 similar devices online.
2. Write what each one does well and what it lacks.
3. Add a flowchart box: “Research → Learn from similar designs”

Questions

1. Did someone already solve your problem?
2. How will your device be better or different?

Activity 6.24 Plan the Features – What Will It Need?

List the important parts your device must have.

Steps

1. In pairs, list parts your device needs (sensor, switch, light, etc.).
2. Add a flowchart decision step like;
“Does the user enter the room? → Yes → Light on / No → Light off”

Questions

1. What must your device include to work properly?
2. What happens when the conditions change?

Activity 6.25 Draw the Full Flowchart – How It Will Work

Create a full working flowchart for your device.

Steps

1. Review all the steps from previous activities.
2. Combine them into a full flowchart showing:
“Start → Sense → Decide → Act → End”
3. Add arrows and label each step clearly.

Questions

1. Does your flowchart show how energy is saved?
2. Can someone follow your flow and understand it?

Activity 6.26 Select the Right Materials Based on Flowchart

Identify what materials your device will need, based on its flowchart steps.

Steps

1. Look at each step in your flowchart.
2. Decide what physical parts are needed for each one (e.g., “sensor” → PIR sensor).
3. Complete a materials table linked to each flowchart box.

Questions

1. Can you build this with the materials available?
2. What parts are hard to get?

Activity 6.27 Build a Simple Prototype Following Your Flowchart

Construct a model of your device using your flowchart as a guide.

Steps

1. Follow your flowchart to build each function step-by-step using basic materials such as cardboard, switches, and wires, and tools such as scissors, glue, and tape.
2. For example, first add the sensor, then connect it to a light.
3. Keep your flowchart beside you as a guide.

Questions

1. Did your build match your flowchart steps?
2. What had to change during the building process?

Activity 6.28 Test Your Device Using Flowchart Conditions

Test your prototype using the logic steps in your flowchart.

Steps

1. Look at each “if-then” step in your flowchart.
2. Try each one in real life. For example:
“If no one is in the room → Light should turn off.”
3. Record whether the device responded correctly.

Questions

1. Did your device behave as expected?
2. Did the test match your flowchart logic?

Activity 6.29 Present Your Flowchart and Device

Explain how your flowchart and device work together.

Steps

1. Prepare a 3-minute presentation.
2. Walk your classmates through the flowchart.
3. Show how each flowchart step happens on your device.

Questions

1. Was your flowchart clear to your audience?
2. Did your device demonstrate the logic?

Activity 6.30 Evaluate and Improve the Flowchart

Reflect on and revise the flowchart and design for improvement.

Steps

- 1. Think about what worked and what didn't in the flowchart.
- 2. Redraw or update any part of your flowchart that needs fixing.
- 3. Share one new idea you would add if building it again.

Questions

- 1. What step in the flowchart needs improvement?
- 2. How can the logic be made simpler or smarter?

DESIGN AND CONSTRUCT ENERGY MANAGEMENT SYSTEMS SOLUTIONS FOR LIGHTING AND CONSUMER APPLIANCES

An **Energy Management System (EMS)** helps to **monitor, control, and reduce** the energy used by lights and electrical appliances. It uses **sensors, microcontrollers, and simple software** to make smart decisions like switching off lights when no one is in a room.

Objectives of an EMS

- a. Help reduce electricity bills
- b. Make lights and appliances last longer
- c. Add convenience by using automation
- d. Allow manual, automatic, or remote control
- e. Provide information to help make smart energy choices

Table 6.1: Core Components of an EMS for Lighting and Appliances

Component	Function
Sensors	Detect things like motion, light levels, or current flow
Microcontroller	Acts like the brain to process information (e.g., Arduino)
Relays/Switch Modules	Switch ON/OFF the connected appliances or lighting circuits
Power Meters	Turn lights or appliances ON and OFF
User Interface	Allow users to control the system (e.g., buttons, screens)

Connectivity Modules	Help with remote control using Wi-Fi or Bluetooth
Power Supply Unit	Gives safe power to run the system (e.g., 5V or 12V)

Methodology for Designing EMS Solutions

Step 1: Conduct a Basic Energy Audit

- Find which appliances or lights use a lot of electricity
- Use a plug-in meter to measure energy usage
- Note when and how people use those appliances

Example: In a classroom, lights and fans stay on even when the room is empty.

Step 2: Define the Problem and Objectives

Problem: Lights stay on when no one is in the room.

Goal: Save 30% of lighting energy by using automatic motion sensors.

Step 3: Select Appropriate Components

Lighting EMS

For Lighting Control

- PIR sensor (to detect people)
- LDR sensor (to check natural light)
- Relay (to turn lights ON or OFF)
- Arduino Uno (microcontroller)
- LED bulbs (low energy use)

For Appliance Control

- Current sensor (e.g., ACS712)
- Real-time clock (to schedule actions)
- Smart plug or Wi-Fi relay
- LCD or IoT dashboard for user display

Step 4: Design the System Architecture

Smart Lighting

- If motion is detected and the room is dark → Lights turn ON
- If no motion for 10 minutes → Lights turn OFF

Smart Appliance

- TV turns OFF automatically after 11 PM
- Iron switches OFF after 15 minutes of no use

Step 5: Develop the Control Algorithm

Sample Code Logic (in simple terms): if (motionDetected && lightLevel < threshold) {turnLightOn();} else if (!motionDetected && timeSinceLastMotion > 10 minutes) {turnLightOff();}

If a person is in the room **and** it is dark → Turn ON the light

If no one is in the room for 10 minutes → Turn OFF the light

Step 6: Build the Prototype

- Connect all components on a breadboard or Vero board
- Use Arduino software to upload your code
- Test each part to see if it works

Step 7: Testing and Calibration

- Install your device in a real location (classroom or home)
- Test how it works during the day
- Ask people what they think and how it can be improved

Practical Example Projects

Project 1: Smart Classroom Light Controller

- Uses: PIR sensor + LDR sensor
- Microcontroller: Arduino Uno
- Outcome: Lights turn on only when needed → About 35% energy saved

Project 2: Appliance Monitor

- Uses: Current sensor + LCD screen
- Sends data to the cloud using Wi-Fi
- Outcome: Helps users see how much energy they use and avoid leaving devices on

Project 3: Remote-Controlled Power Strip

- Controls: TV, fan, or heater
- Uses: Smartphone app and Wi-Fi module
- Outcome: Users can turn devices on/off from anywhere and set schedules

Considerations during Design

- **Safety first:** Use fuses, proper casing, and isolated relays
- **Make it expandable:** Plan for adding more devices later
- **Keep it simple:** Use easy-to-understand buttons or apps
- **Keep costs low:** Use affordable parts found in local markets

- **Plan for power backup:** A small battery or UPS can help keep the system running

Evaluation Metrics

Metric	How to Measure
Reduction in energy usage	Compare electricity use before and after installation
System reliability	Check how often it works without failing
User satisfaction	Ask users if it is helpful and easy to use
Cost savings	Look at your reduced electricity bills

Conclusion

Creating a basic EMS helps you and communities reduce energy waste and save money. These systems are easy to build using sensors, microcontrollers, and simple programming. They also encourage people to think about the environment and use energy more responsibly.

Practical Context Example

Project Title: Smart Energy Management System for a Rural Classroom

Problem: In a basic school in the Upper East Region, classroom lights and ceiling fans are left on even when the room is empty or when there is enough daylight. The school has a solar system and limited battery storage, so energy conservation is crucial.

Project Goal

Build a simple system that turns off lights and fans when:

- There is enough natural daylight
- The room has been emptied for 5 minutes or more

Materials Needed

- Arduino Uno
- LDR (to check light levels)
- PIR sensor (to detect people)
- Relay module (to control light and fan)
- LED bulbs
- Solar system (already available in the school)
- Wires, resistors, and a case for the components

Steps to Build

1. Check how energy is being wasted

2. Set the requirements for your device
3. Use Proteus or Tinker cad to draw and test your circuit
4. Write code for Arduino to read sensors and control relays
5. Build the circuit and install it in the classroom
6. Test for a few days, then improve based on feedback

Arduino Logic (Simplified Pseudocode)

If (LDR detects low light AND PIR detects motion) {Turn ON light}

Else if (No motion for 5 minutes) {Turn OFF light and fan}

Activity 6.31 Investigating Energy Waste at Home

Identify areas where energy is wasted through lighting and appliances in a typical home.

Steps

1. Think about how lights and appliances are used at home.
2. In groups, draw a typical home layout and mark where lights and appliances are often left on unnecessarily.
3. Discuss how this leads to energy waste.
4. Present your findings to the class.

Guiding Questions

1. Where do people forget to switch off lights or appliances most often?
2. How could simple changes reduce energy waste?

Either undertake Activities 6.32, 6.33 and 6.34 or Activities 6.37 and 6.38

Activity 6.32 Create an Ideal Lighting Control Plan

Design a basic plan to manage lighting more efficiently.

Steps

1. Draw a room layout with light sources marked.
2. Suggest where to place motion sensors or timers.
3. Label the types of control (e.g., timer, dimmer, sensor).
4. Share your plan with another group for feedback.

Guiding Questions

1. Which rooms need automated lighting?
2. How do sensors help in saving energy?

Activity 6.33 Using Flowcharts to Plan EMS Design

Use a flowchart to outline steps for designing an energy management system.

Steps

1. Learn what a flowchart is and how it shows steps.
2. Create a flowchart for EMS design (e.g., identify energy waste → choose device → design control → install → test).
3. Discuss and explain each step to your group.

Guiding Questions

1. Why is it important to plan with a flowchart?
2. What step comes after choosing a device?

Activity 6.34 Build a Simple Automatic Light Controller

Construct a basic lighting system using a motion sensor.

Steps

1. Set up the circuit using the breadboard, PIR motion sensor, relay module, power source, jumper wires, and LED bulb.
2. Test the system – does the light turn on with motion?
3. Adjust sensitivity or time delay as needed.

Guiding Questions

1. How does the motion sensor control the light?
2. Where would this system work best?

These next TWO Activities are Optional Extra activities (6.35-6.36)

Activity 6.35 Simulate Energy Usage with an Online Tool (Optional extra)

Simulate how much energy appliances use with and without EMS.

Steps

1. Enter the wattage and usage time of appliances on a simulator.
2. Calculate energy consumption with and without smart controls.
3. Compare results and discuss.

Guiding Questions

1. How much energy can you save by turning off appliances earlier?
2. Which appliance uses the most energy?

Activity 6.36 Compare Manual vs. Automated Systems (Optional extra)

Understand the difference between manual and automated energy systems.

Steps

1. Set up two lighting systems using switches, timers, motion sensors, and lamps: one manual and one with a timer.
2. Measure how long each light stays on for in a fixed time.
3. Discuss the energy implications.

Guiding Questions

1. Which system saves more energy?
2. How can automation improve energy use?

Either undertake Activities 6.37 and 6.38 or Activities 6.32, 6.33 and 6.34

Activity 6.37 Design an Energy-Efficient Smart Room

Design a “smart room” using EMS solutions.

Steps

1. In groups, draw a room (e.g., kitchen or bedroom).
2. Add smart devices (such as timers, sensors, smart plugs) that would help manage energy use.
3. Present the energy-saving benefits of your design.

Guiding Questions

1. Which smart devices are best for this room?
2. How does this room reduce electricity use?

Activity 6.38 Create an EMS Flowchart for Consumer Appliances

Use a flowchart to describe EMS for household appliances.

Steps

1. Choose an appliance (e.g., fan, TV, heater).
2. Create a flowchart showing how to control its energy use (e.g., add a smart plug → connect to an app → set usage schedule).
3. Share your chart with the class.

Guiding Questions

1. What control method works best for this appliance?
2. What are the steps to automate its use?

These next Activities are Optional Extra activities (6.39-6.41)

Activity 6.39 Group Discussion — “What If EMS Didn’t Exist?” (Optional Extra)

Appreciate the value of EMS solutions by imagining a world without them.

Steps

1. Discuss what would happen if homes and buildings had no EMS.
2. Think of real problems like energy bills, overuse, or fire risks.
3. Present your views to the class.

Guiding Questions

1. What problems arise from poor energy management?
2. How does EMS solve these problems?

Activity 6.40 Real-World EMS Observation Project (Optional Extra)

Observe EMS devices in use and report their impact.

Steps

1. Visit a place with automated lights, timers, or smart plugs.
2. Record how they operate and when they activate.
3. Interview someone about their benefits.
4. Share findings with your group.

Guiding Questions

1. What EMS devices did you see?
2. How do they reduce energy use?

Activity 6.41 Designing and Auditing an Energy Management System for a Classroom (Optional)

Materials Needed

- Energy-saving devices (e.g. LED bulbs, motion sensors, smart plugs)
- Multimeters, clamp meters, and thermometers
- Infrared thermometers or thermal sensors
- Power consumption meters (e.g. Kill-A-Watt)
- Arduino/microcontroller (optional for EMS design)
- Breadboards, jumper wires, relays, resistors
- Laptops with CAD/CAM tools and spreadsheets
- Energy audit checklist templates

- Flipcharts or whiteboard
- Classroom appliances (e.g. fans, lights, kettles)

Steps

Part 1: Device Identification and Application

1. In small groups, examine and describe the function of 3–5 energy-saving devices.
2. Discuss and list suitable application areas for each device (e.g., motion sensor for lighting, smart plug for appliances).

Part 2: Methodology for Energy-Saving Design

3. Each group outlines steps to design an energy-saving device, identifying:
 - Target system (e.g. lighting)
 - Input/output (sensors, relays)
 - Control logic (on/off, dimming, timer)

Part 3: Energy Management System Design

4. Design and build a prototype EMS using basic electronics (e.g., PIR sensor + LED + Arduino).
5. Test the circuit and observe behaviour in real-time.

Part 4: Measurement of Energy Usage

6. Use instruments (e.g., multimeter, wattmeter) to:
 - Measure voltage, current, and power usage of appliances
 - Detect temperature differences in thermal systems

Part 5: Energy Audit and Management Plan

7. Conduct a basic walk-through energy audit of the classroom.
 - Record appliance types, usage duration, and power ratings
 - Identify inefficiencies or unnecessary loads
8. Based on findings, draft a Basic Energy Management Plan:
 - a. Set energy-saving goals
 - b. Recommend energy-saving devices and practices
 - c. Estimate potential savings

Questions

1. What devices did you identify, and how do they contribute to energy conservation?
2. Which application areas are best suited for each device, and why?
3. What were the main challenges in designing your energy management system?
4. How did you verify the accuracy of your energy measurements?
5. What did your energy audit reveal about how energy is used in your classroom?

6. Suggest three energy-saving measures based on your audit findings.
7. How can thermal losses be identified and reduced in a school setting?
8. How could your energy management system be improved for real-world use?

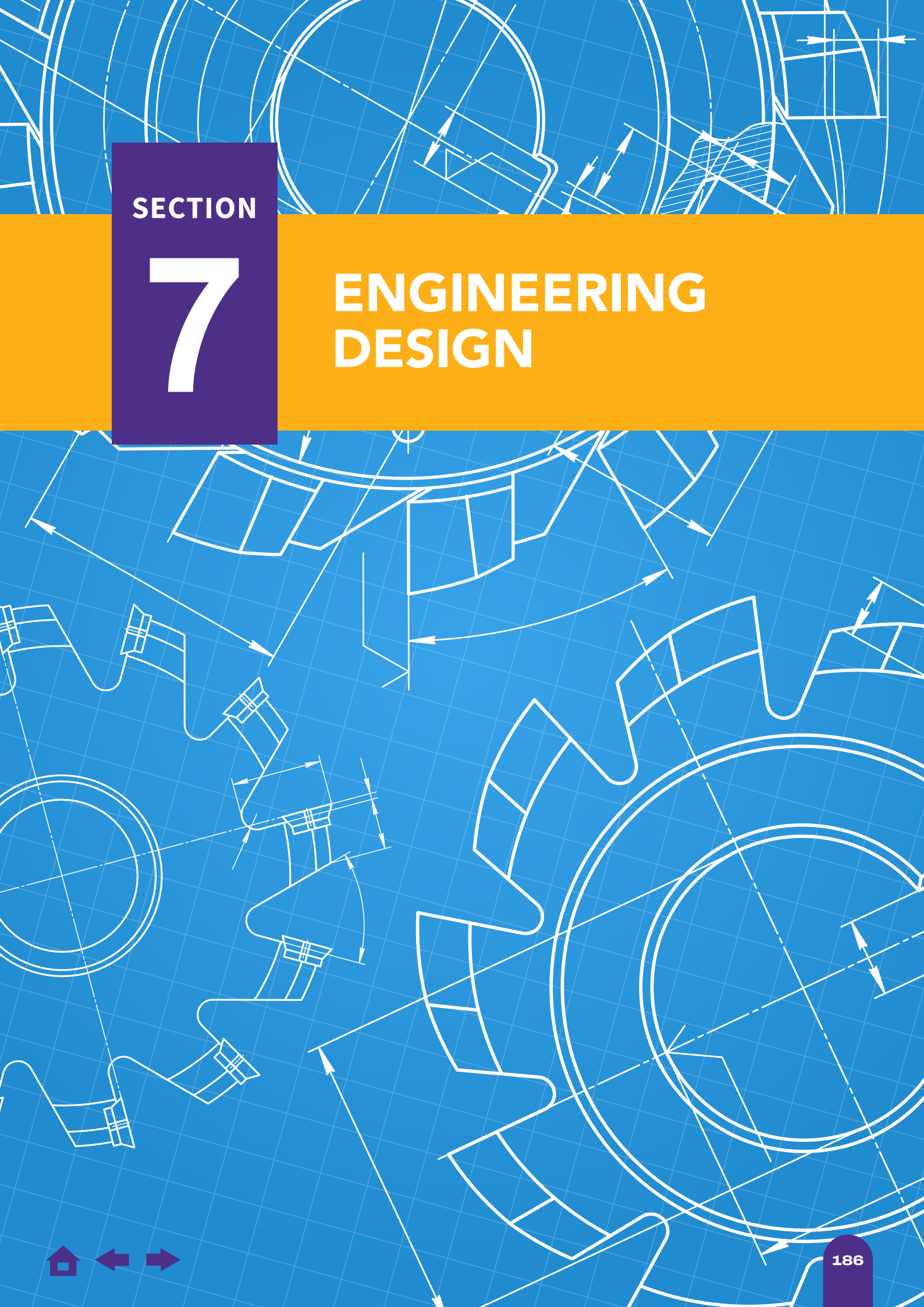
EXTENDED READING

Kumar, A., Prakash, O., Chauhan, P. S., Gautam, S. (2020). Energy Management: Conservation and Audits. United States: CRC Press.

REVIEW QUESTIONS

1. Your school recently installed motion sensors in the main hall to control lighting. Explain how this device helps conserve energy in that area.
2. Your science teacher uses dimmer switches to control the brightness of the lights during presentations. How does this device support energy conservation?
3. A student installs a timer switch for garden lights at home that turns them off at midnight. Describe how this setup helps save energy.
4. Your neighbour installed solar-powered garden lamps. How do these lamps contribute to energy conservation?
5. In a new office building, occupancy sensors are installed in meeting rooms. Explain how they help reduce energy usage.
6. A student uses a smart plug to control their television and prevent it from staying on standby mode. How does this practice conserve energy?
7. Your school replaced all fluorescent lights in the library with LED bulbs. What makes LED bulbs a better choice for energy conservation?
8. A learner installs a home energy monitor and notices high energy use during certain hours. How can this device help improve energy conservation at home?
9. Your uncle uses a smart thermostat to control his home's air conditioning system. How does this device help reduce electricity bills and conserve energy?
10. The local government installed photocells in streetlights that automatically turn off in the morning. Explain the benefit of using photocells for energy conservation.
11. Your school recently installed motion sensors in all the classrooms. Explain where and why motion sensors are used for energy conservation.
12. Your neighbour uses a timer switch to control their outdoor lights. What is the application area of timer switches in energy conservation?
13. At a supermarket, the lights in the refrigerator section dim when no one is around. Which energy-saving device is likely to be used, and what is its application area?
14. A classmate says their home uses dimmer switches to reduce light brightness. Explain how dimmer switches help conserve energy.
15. In a hotel, hallway lights are turned on automatically when someone walks by. Identify the device used and the application area.
16. Your school's solar-powered security lights only turn on at night. What energy-saving device is likely in use, and what is its application?
17. A factory installs smart plugs that turn off machines during non-working hours. What is the application area of smart plugs?
18. A computer lab uses a central control system to turn off all computers at 6 PM daily. What energy-saving device is in use, and what is its application?
19. A street lighting system automatically adjusts brightness based on the time of night. What device is used, and where is it applied?

20. A home automation app allows users to turn off appliances from their phones. What is this device called, and what is its application area?
21. You and your team are asked to design a device that turns off lights when no one is in the room. What is the first step you should take in the design process?
22. Your group wants to design a fan that automatically turns off after 30 minutes. What should you do after identifying the problem?
23. You plan to design a solar-powered garden light. What step involves creating rough sketches or drawings of how it will look and work?
24. In designing a motion sensor light, which step involves choosing the best idea out of all the ones your team brainstormed?
25. Your team wants to test if a dimmer switch saves energy. Which step of the design process does this relate to?
26. After testing your energy-saving device, you discover that it doesn't switch off quickly enough. What should you do next?
27. You're writing out the steps for designing an energy-efficient water heater. What is this list of steps called?
28. What is the purpose of using a flowchart in the design process for an energy-saving device?
29. Your classmate skips the testing stage when designing a sensor-based power switch. What is the risk of doing this?
30. After completing the design and testing of your device, what is the final step in the methodology?
31. Your school's hallway lights are often left on even when no one is around. Design a simple system to reduce energy use.
32. You are asked to design a smart system for home lighting that adjusts brightness depending on the time of day. What would you include?
33. Your team is building a system to manage the energy use of TVs and fans in a home. What components would you use?
34. During testing, your lighting control system sometimes turns off lights while people are still in the room. What can you do?
35. You want to make a system where all the lights in a house can be controlled using a phone. What technologies would you use?
36. You are designing an energy-saving solution for outdoor lights that should only turn on at night. What sensor do you use?
37. Your team is asked to build a system that prevents phone chargers from drawing power after the battery is full. What is your solution?
38. You've completed a system to reduce fan usage based on room temperature. How would you test and improve it?
39. You are to design a system for switching off unused classroom appliances after school hours. What design approach would you use?
40. Your design project requires you to build and present an energy management system for a bedroom. What are three key features it should have?

The background of the entire page is a technical drawing on a blue grid. It features various mechanical components, including gears of different sizes, shafts, and structural frames. White lines and arrows are used to indicate dimensions, movement, and assembly points. The drawing is a complex, overlapping composition of these elements.

SECTION

7

ENGINEERING DESIGN

SYSTEMS DESIGN AND PROTOTYPING

INTRODUCTION

This section exposes you to the iteration to improve engineering designs. An essential part of the engineering design process is testing and validating a prototype. It entails determining if a prototype satisfies the design specifications and performs dependably in practical settings. In this process, the prototype is compared to the design specifications, stakeholders' input is gathered, the design is iteratively improved based on testing outcomes, and industry standards compliance is confirmed. You will understand that before going into production, a prototype can be refined for effectiveness, dependability, and general usability through extensive testing and validation. Additionally, before the product is completed for mass production or deployment, this procedure guarantees that any issues or flaws are found and fixed. Although prototypes sometimes fail in their early stages, they are a crucial element of the engineering and design process. Instead of being indicators of bad design, these errors present worthwhile chances to grow, learn, and hone the solution. You will be allowed to closely examine these problems, pinpoint the underlying reasons, address them, and improve the prototype's dependability, performance, and safety.

KEY IDEAS

- **Documentation and Communication:** Accurate documentation of testing results, failures, and improvements is essential for effective communication, collaboration, and informed decision-making.
- **Failure Analysis and Problem-Solving:** Analysing failures helps identify design, material, or process flaws and guides necessary improvements through root cause analysis.
- **Iterative Design and Feedback Integration:** Prototyping is an iterative process where feedback and observations from testing are used to refine, redesign, and enhance the solution.
- **Prototype Testing and Validation:** Prototypes should be tested under various real-world conditions using different variable constraints to ensure they meet design specifications, function reliably, and perform safely.

TEST AND VALIDATE A PROTOTYPE

Testing and improving a prototype is a very important step in the engineering design process. It helps you check if the prototype works well, meets the design goals, and can perform under real-life conditions. During testing, you compare the prototype to your original plan, collect feedback from users or team members, and make changes based on what you learn.

This helps make the design better, more reliable, and ready for use. Testing also helps you find and fix any problems before the final version is made or used.

1. Purpose of Testing and Validation

Testing and validation help make sure a prototype or product works well before it is produced in large numbers. Testing checks how well the product works, how strong it is, and how easy it is to use in real-life situations. It also helps find problems so the design can be improved. Validation checks if the product meets the required rules, standards, and user needs.

Together, testing and validation help reduce mistakes, improve the design, and make sure the final product is safe, reliable, and ready to use.

- a. **Confirm Functionality:** Check if your prototype works the way you planned. Make sure all the parts are connected properly, and the system can do the job it was designed for. This step helps you know if your idea is working in real life.
- b. **Measure Performance:** Test how well your prototype works. Look at things like how fast it works, how accurate it is, how much energy it uses, and how well it does its job in different situations.
- c. **Ensure Safety and Reliability:** Check if the prototype is safe to use and can work well over time without breaking. This helps prevent accidents and makes sure the prototype can be trusted by users.
- d. **Gather User Feedback:** Let others try your prototype and watch how they use it. Ask them what they think. This helps you understand if it's easy to use and what you can do to make it better.
- e. **Support Design Improvements:** Use the test results and feedback to find out what needs fixing. Make small changes to improve the prototype. This process helps you create a final version that works better and is easier for people to use.
- f. **Validate Real-World Applicability:** Try out your prototype in the real world, not just in a classroom or lab. See how it handles things like weather, power supply, or how people use it. This shows if it's ready to be used outside in real situations.

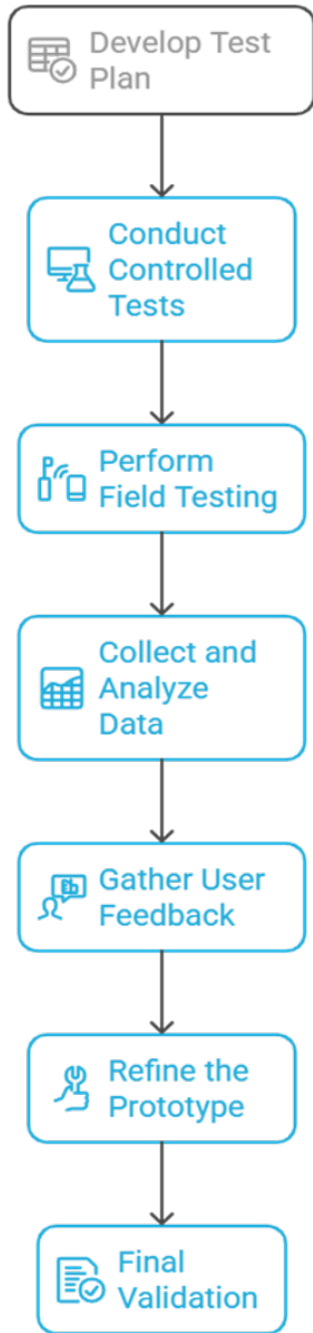


Figure 7.1: A flow chart of Validation

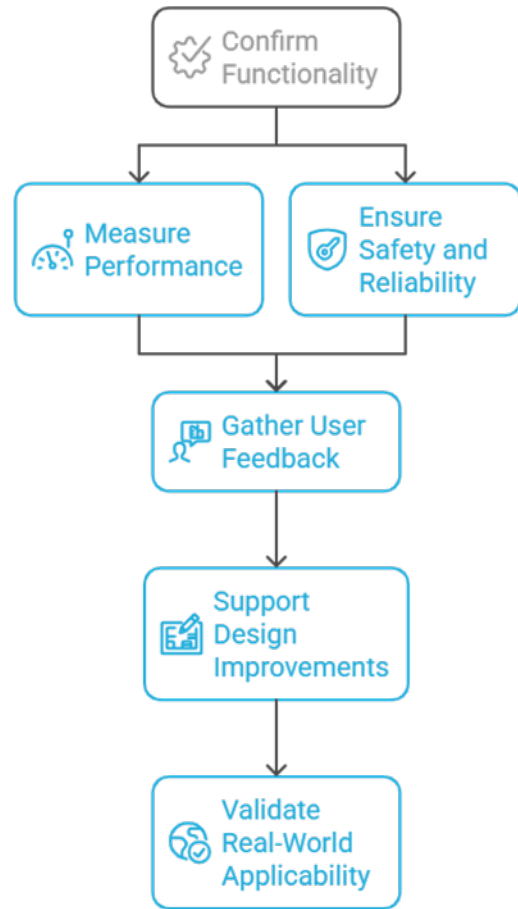


Figure 7.2: A flow chart of Functionality

2. Key Steps in Testing and Validation

Testing and validation help ensure that a prototype or system works well and meets all the necessary requirements before it is fully used. The key steps include carefully checking the product to find possible problems, improving its performance, and making sure it follows the right rules and standards. This structured process helps designers fix issues early, reduce risks, and create a more reliable and effective final product.

Step 1: Develop a Test Plan

Begin by creating a clear test plan that explains what needs to be checked, such as energy efficiency, how the system responds, and how easy it is to use. Choose the most suitable method to carry out the tests. This could include using computer models, testing in a laboratory, or trying it out in real conditions. Set clear goals for success, for example reaching ninety percent accuracy or saving thirty percent energy. These goals help measure how well the prototype meets its original design objectives.

Step 2: Conduct Controlled Tests

After making the test plan, the next step is to run tests in a safe and controlled environment like a lab. Use tools such as multimeters, data loggers, or computer simulations to check how fast, accurate, and energy-efficient the prototype is. Testing in the lab helps find problems early in a setting where conditions can be carefully managed. It also gives a starting point for more testing later.

Step 3: Perform Field Testing

Field testing means trying out the prototype in the real place where it will be used, like a home or garden. This helps to see how it works in real-life situations, such as changes in weather, how people use it, or differences in power supply. Field testing shows whether the prototype is strong, useful, and ready to handle everyday challenges.

Step 4: Collect and Analyse Data

While testing the prototype in the lab and in real-life settings, it is important to record how it performs over time. These results are compared with the original goals to check for any problems or weak areas. By looking at this information, developers can see if the prototype works as expected and find ways to make it better.

Step 5: Gather User Feedback

User feedback helps us understand how people use the prototype in real life. This means asking users what they think about how easy it is to use, how clear the interface is, and how satisfied they are overall. Their opinions help us spot problems that technical tests might miss, such as confusion or difficulty using the product.

Step 6: Refine the Prototype

After collecting test results and user feedback, changes are made to improve the prototype. This means fixing any problems found and making it work better for users. Once the changes are done, the improved prototype is tested again to make sure it now works as planned and meets its goals.

Step 7: Final Validation

After all improvements are made, the prototype goes through a final check to make sure everything works properly. Engineers confirm that it meets the design goals, works well, and satisfies user needs. A final report is then written to explain the test results, the changes that were made, and how well the prototype performs its intended job.

Real-World Example of a Valid Prototype

Project Title: Smart Solar-Powered Irrigation System for Small Gardens

Objective: To save water and energy by automatically watering a garden only when the soil is dry. The system is powered by solar energy.

1. Prototype Description

The prototype included

- a. Soil moisture sensors to check if the soil is dry.
- b. Arduino Uno to read sensor data and control the system.
- c. Relay module to turn the water pump on and off.
- d. Solar panel and battery to power the system without electricity from the grid.
- e. LCD display to show soil moisture levels and system status.

2. Testing and Validation Process

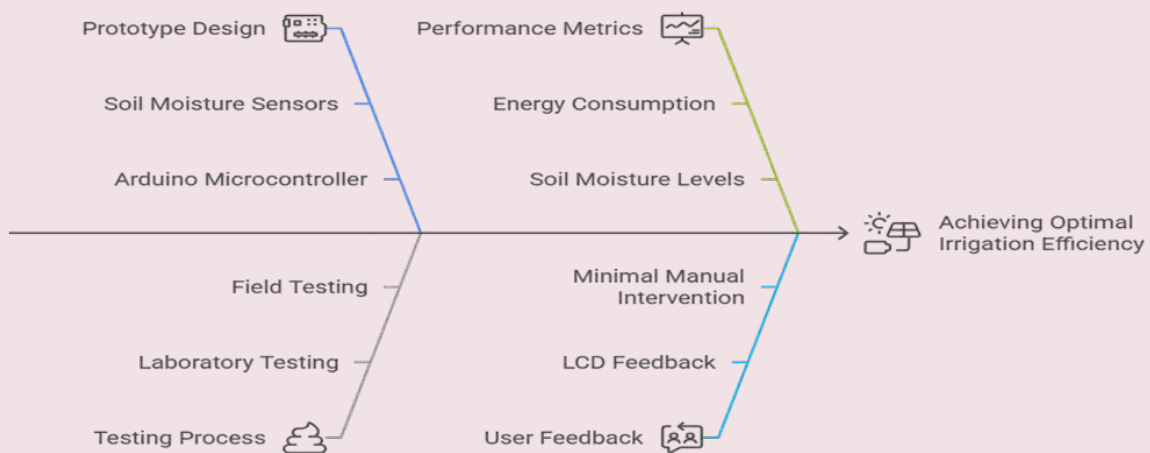
- a. Laboratory Testing
 - i. Each part was tested separately
 - The moisture sensors were checked using dry, damp, and wet soil.
 - The water pump was tested for how fast and how well it pumped water.
 - The solar panel was tested to see how well it charged the battery.
 - ii. The full system was put together on a breadboard and tested using made-up data to simulate real conditions.
- b. Field Testing (Real Garden)
 - i. The system was placed in a real vegetable garden.
 - ii. It was monitored for 7 days during different weather conditions.
 - iii. Important data was recorded, including:
 - How often and how long the pump was used.
 - Battery voltage levels throughout the day.
 - Soil moisture levels before and after watering.
 - Solar panel performance on sunny and cloudy days.
- c. Results
 - i. The garden soil stayed at a good moisture level without wasting water.
 - ii. All energy needs were met by the solar panel.
 - iii. The battery stayed about 85% charged on average.
 - iv. Users liked the LCD display and that they didn't need to do much manually.

d. Improvements Made

- The moisture level setting was adjusted to avoid watering during light rain.
- A waterproof case was added to keep the Arduino safe.
- A second solar panel was added to help during cloudy days.

Conclusion

Testing a prototype helps ensure it works well in real-life situations. The Smart Solar-Powered Irrigation System is a good example of a working prototype. It helped save water and energy and got positive feedback from users, showing it is useful for home gardens and small farms.



Activities – choose THREE of the following activities 7.1 – 7.10 (the rest are optional)

Activity 7.1 Phone Stand Prototype

To design, build, and test a cardboard phone stand, identify stability issues, and modify the design to improve functionality and balance.

Steps

1. Design a simple phone stand using cardboard.
2. Assemble the prototype.
3. Test it with different phone sizes.
4. Observe if it wobbles or falls over.
5. Adjust the design to fix any issues.

Questions

1. Does the phone sit comfortably on the stand?
2. What caused the stand to wobble or tip over?
3. How can the design be changed to improve stability?

Activity 7.2 Water Bottle Holder for Bicycle

To design, test, and improve a bike bottle holder prototype, observing stability and identifying modifications to enhance grip and security.

Steps

1. Create a prototype using the materials provided.
2. Attach it to the bike frame.
3. Insert a bottle and ride over a short rough patch.
4. Observe movement or slippage.
5. Modify the design to hold better.

Questions

1. Did the holder keep the bottle secure?
2. Which parts of the design failed under movement?
3. What materials or shapes can improve the grip?

Activity 7.3 Desk Organiser Prototype

To design, build, and test an organiser for at least three items, evaluate its functionality, and modify the design based on observations and peer feedback.

Steps

1. Design an organiser to hold at least 3 items.
2. Assemble and place items in it.
3. Check if any items fall out or don't fit.
4. Get feedback from classmates.
5. Redesign and test again.

Questions

1. What items did not fit well?
2. Which section needs resizing or reinforcement?
3. What suggestions did you receive from others?

Activity 7.4 Eco-Friendly Shopping Bag

To design, sew, and test a reusable bag, identify weak points, make improvements, and ensure it can carry items securely and comfortably.

Steps

1. Design and sew a reusable bag.

2. Test it by carrying different items.
3. Check for tearing, comfort, or poor stitching.
4. Repair and improve weak areas.
5. Retest for validation.

Questions

1. Did the bag hold all items securely?
2. Which part failed and why?
3. How did you strengthen the design?

Activity 7.5 Mini Greenhouse Prototype

To design and test a small greenhouse prototype, monitor environmental conditions, compare plant growth, and adjust the design to optimise performance.

Steps

1. Design a small greenhouse structure.
2. Place it over a planted tray.
3. Monitor temperature and humidity daily.
4. Compare plant growth with an open-air tray.
5. Adjust the design if it overheats or dries up.

Questions

1. How did your prototype perform compared to the control?
2. What changes made it work better?
3. What real-world applications does this have?

Activity 7.6 Key Holder Prototype

To design, build, and test a wall-mounted key holder, identify structural weaknesses, and modify the design to ensure stability and functionality.

Steps

1. Design a wall-mounted key holder.
2. Mount it and hang various keys.
3. Observe any bending or falling.
4. Reinforce weak areas or change the layout.
5. Retest.

Questions

1. Did the key holder stay attached?

2. What caused failure in the structure or wall mount?
3. How did you fix the problem?

Activity 7.7 Book Holder for Bedside

To design, test, and improve an under-bed book holder, ensuring it securely accommodates different book sizes and resists movement-related slippage.

Steps

1. Create a holder to fit under a pillow or mattress.
2. Test it with different book sizes.
3. Check if books slide out when adjusting the bed.
4. Improve angles or materials.
5. Retest.

Questions

1. What book sizes worked or didn't?
2. How did user movement affect the design?
3. What could be added to prevent slippage?

Activity 7.8 Mini Fan Guard

Test a prototype safety cover for a small USB fan.

Steps

1. Design a guard that allows airflow but blocks fingers.
2. Attach it to the fan.
3. Turn on the fan and test for airflow and safety.
4. Check for overheating or blockages.
5. Redesign and improve.

Questions

1. Was airflow affected?
2. Did the guard prevent finger access?
3. How did you improve safety without reducing function?

Activity 7.9 Pen Cap Holder for Desks

Validate a prototype that holds multiple pen caps to reduce loss.

Steps

1. Create a strip to insert pen caps.
2. Mount it on the desk.
3. Test inserting/removing different caps.
4. Evaluate how well it grips and organises.
5. Modify grip design and retest.

Questions

1. Did the prototype hold all pen caps securely?
2. Was it easy to use?
3. What improvement did you make for better grip?

Activity 7.10 Laptop Cooling Stand

Test if the cooling stand prototype reduces laptop heat.

Steps

1. Design a raised stand with airflow space.
2. Use the laptop on it for 30 minutes.
3. Measure and record temperature.
4. Add passive (holes) or active (fan) cooling options.
5. Retest and compare.

Questions

1. Did your design lower the laptop temperature?
2. What part helped the most in cooling?
3. How can you make it more efficient or portable?

ANALYSING FAILURES ASSOCIATED WITH PROTOTYPES AND PROVIDE APPROPRIATE REMEDIES

Prototyping is an important part of the engineering and design process. During the early stages, prototypes may not work as expected. These early problems are not signs of poor design. Instead, they are chances to learn, improve, and make the solution better. By

studying what went wrong, designers can find the cause, correct it, and make the prototype work more safely, reliably, and effectively.

Types of Failures in Prototypes

a. Functional Failures

These happen when the prototype does not carry out the main task it was designed for.

Example: A sensor does not detect changes, or a motor does not turn on.

b. Performance Failures

The prototype does the task, but it does so in a weak, slow, or inefficient way.

Example: The system gives wrong readings, works slowly, or uses too much power.

c. Structural Failures

Parts of the prototype break or stop working due to damage or wear.

Example: The casing lets in water, wires become loose, or moisture causes damage.

d. Electrical Failures

These occur when there are power issues, short circuits, or burnt-out parts.

Example: The battery stops holding power, or parts become damaged from high voltage.

e. User Interface Failures

The person using the prototype has trouble understanding or using it.

Example: The display is confusing, buttons are hard to find, or messages are unclear.

Real-World Example: Smart Solar-Powered Irrigation System

Prototype Objective Recap: To create an automatic irrigation system that uses solar power. It turns on based on soil moisture and shows messages on an LCD screen.

Failures Encountered and Their Analysis

Type of Failure	Description of Failure	Root Cause	Remedy/Improvement
Performance Failure	Watering system activated even during rain or wet conditions	Soil moisture threshold too low, no weather compensation	Adjusted the sensor threshold; added rain detection through sensor/logic adjustment
Electrical Failure	System stopped functioning on overcast days due to battery draining	Solar panel size was too small for consistent energy supply	Added an extra solar panel and used a higher capacity rechargeable battery

Structural Failure	Arduino and sensor connections became unstable due to moisture exposure	No proper weatherproof enclosure	Installed a sealed, weatherproof casing and used silicone to seal wiring points
User Interface Failure	Users couldn't interpret the LCD readings clearly	LCD messages were unclear and not user-friendly	Updated LCD code with clearer, concise status messages (e.g., "Watering in Progress")
Functional Failure	Pump occasionally failed to activate even when soil was dry	Relay module connection was loose; power spike issue	Secured wiring with soldering and used a diode for back EMF protection from the pump

Remedies and Best Practices

- a. Strengthen the Design
 - i. Choose strong parts that are suitable for outdoor use.
 - ii. Use proper connections like soldering and heat-shrink tubing to avoid loose wires.
- b. Add Feedback Tools
 - i. Use lights or screens to show what the system is doing
 - ii. Include code to detect and report problems such as disconnected sensors.
- c. Test in Different Situations: Try out the prototype in many conditions such as hot, cold, wet, or dry weather.
Check how it performs when power is low, or components are under stress.
- d. Build in Parts That Can Be Replaced: Make the design in a way that allows one part to be replaced or upgraded without changing the whole system.
- e. Keep Clear Records: Write down all test results, what went wrong, why it went wrong, and how it was fixed.

Conclusion

Problems during prototyping are not failures. They are part of learning and improving. By studying what went wrong, engineers can make better and stronger designs. In the Smart Solar-Powered Irrigation System, early problems helped the team make changes that improved how it worked, how long it lasted, and how easy it was to use.

Activities – choose TWO of the following activities 7.11 – 7.19 AND 7.20 (three in total - the rest are optional)

Activity 7.11 Broken Phone Stand

Design a durable and stable phone stand.

Steps

1. In groups, identify user needs.
2. Define the problem: many phones stand up or break.
3. Sketch designs, then laser-cut or hand-cut one.
4. Test with different phone sizes and surfaces (table, bed, tilted board).
5. Note failures (e.g., tipping, collapsing).
6. Modify design, retest, and reflect.

Questions

1. Why did your prototype fail under certain conditions?
2. What design changes improved its stability?

Activity 7.12 Leaky Water Bottle Holder

Build a secure holder for water bottles on school bags.

Steps

1. Empathise with students who walk/cycle with water bottles.
2. Define needs: holder must be secure, washable, and not leak.
3. Prototype using fabric and cardboard.
4. Test by shaking the bag, walking, and checking for water marks.
5. Identify weak spots (e.g., poor grip, leakage).
6. Redesign using a more suitable material (plastic sheet?).

Questions

1. What caused the leakage or fall?
2. How did your team fix the weak points?

Activity 7.13 Uncomfortable Chair Design

Design a comfortable chair using available materials.

Steps

1. Interview users about uncomfortable chairs.
2. Build a prototype using foam and structure.
3. Test with multiple users; ask for feedback.
4. Observe collapses, discomfort, instability.

5. Redesign with feedback and test again.

Questions

1. What caused discomfort or breakage?
2. What user feedback helped improve your design?

Activity 7.14 Emergency Lantern for Load Shedding

Build a rechargeable light source for power outages.

Steps

1. Empathise: ask classmates what's needed during blackouts.
Define the need: must be bright, rechargeable, and portable.
2. Design and build with simple electronics.
3. Test brightness in the dark; check battery duration.
4. Identify failures (dim light, short battery life).
5. Modify circuit or enclosure, retest.

Questions

1. What limited the light's performance?
2. What did you change to improve battery life or brightness?

Activity 7.15 Unstable Bicycle Accessory Mount

Build a stable mount for holding a flashlight on a bike.

Steps

1. Define the need: light must remain in place while biking.
2. Design a mount using soft and hard materials.
3. Test during movement or shaking simulation.
4. Watch for slippage, angle shift, or breakage.
5. Redesign for better grip or stronger material.

Questions

1. What caused the flashlight to move or fall?
2. How did you improve the grip or strength?

Activity 7.16 Hand-Free Door Opener

Create a foot-operated door opener.

Steps

1. Design a foot pedal that pulls/pushes the door.
2. Install and test with multiple users.
3. Observe comfort, effectiveness, and breakage.
4. Redesign with ergonomic or strength feedback.

Questions

1. Was the mechanism strong enough?
2. Did users find it comfortable and easy to use?

Activity 7.17 Overloaded Backpack Breaks Strap

Design a strap system for heavy backpacks.

Steps

1. Interview users who carry heavy loads.
2. Build strap prototype with padding and reinforcements.
3. Load up the backpack and test over time.
4. Observe tear points, discomfort, strap slippage.
5. Reinforce stress areas and retest.

Questions

1. Where did the straps show stress or wear?
2. How did you fix the issue?

Activity 7.18 Mini Home Model with Weak Roof

Create a model of a house that withstands wind or light rain.

Steps

1. Build a scale model.
2. Test with fan (wind) and water spray.
3. Record damage or collapse.
4. Identify flaws (roof design, joints).
5. Strengthen structure and retest.

Questions

1. What caused failure in the weather test?
2. What improved the structural integrity?

Activity 7.19 Noisy Door Alarm Fails to Detect Entry

Design a sensor alarm to detect door opening.

Steps

1. Prototype magnetic or pressure-based switch.
2. Test door open/close scenarios.
3. Observe false triggers or missed triggers.
4. Modify sensitivity, placement, and wiring.

Questions

1. When did the alarm fail?
2. What fixed the false alarms or delays?

This final activity wraps all the learning from Y1-Y3 together. This will help you recap all you have learnt under this section.

Activity 7.20 Design, Build, and Evaluate a Smart Lighting System Prototype

Materials Needed

- Breadboard or PCB
- Arduino board (Uno/Nano)
- Sensors (e.g., PIR sensor, LDR)
- LEDs and resistors
- Jumper wires
- 5V Power supply
- Multimeter
- Laptop with Arduino IDE
- Worksheets for documentation
- Flipchart or board for presenting ideas

Steps

1. **Problem Definition & Requirement Gathering**
 - a. You are given a real-world problem (e.g., reducing energy waste in classrooms).
 - b. In groups, discuss and **document solution requirements** such as automation, energy efficiency, cost-effectiveness, and safety.
 - c. Develop and record **research questions**, such as:
 - i. What components are needed for automated lighting?

ii. How can energy usage be reduced using sensors?

2. Solution Exploration

- Brainstorm and **analyse at least three possible solutions** (e.g., manual switch system, IR-based automation, LDR-PIR hybrid).
- Compare solutions based on criteria (efficiency, cost, usability) and **justify the choice of the optimal solution**.

3. Prototype Design and Construction

- Draw a circuit diagram based on the selected solution.
- Assemble the prototype using Arduino and sensors according to the design specifications.

4. Testing and Validation

- Upload and test the Arduino code.
- Observe and record prototype behaviour under different lighting/motion conditions.
- Use instruments (multimeter, serial monitor) to **test and validate** the performance (response time, power usage, accuracy).

5. Failure Analysis and Improvement

- Note any **failures or unexpected behaviours** (e.g., delayed light response, sensor errors).
- Troubleshoot and **document remedies** such as rechecking connections, adjusting thresholds, or improving code.

6. Final Presentation and Documentation

Prepare a short group presentation including:

- Initial problem and solution requirements
- Design process and research questions
- Prototype demonstration
- Test results and improvements made
- Final conclusions

Questions

- What problem did your prototype aim to solve, and what were the key requirements?
- What research questions helped guide your prototype design?
- List the different solutions you considered. Why did you choose the final one?
- How did your prototype perform during testing? What data supports your findings?
- What problems did you encounter, and how did you solve them?
- How does your final design meet the user requirements and real-world application?

EXTENDED READING

Cross, N. (2021). Engineering Design Methods: Strategies for Product Design. United Kingdom: Wiley.

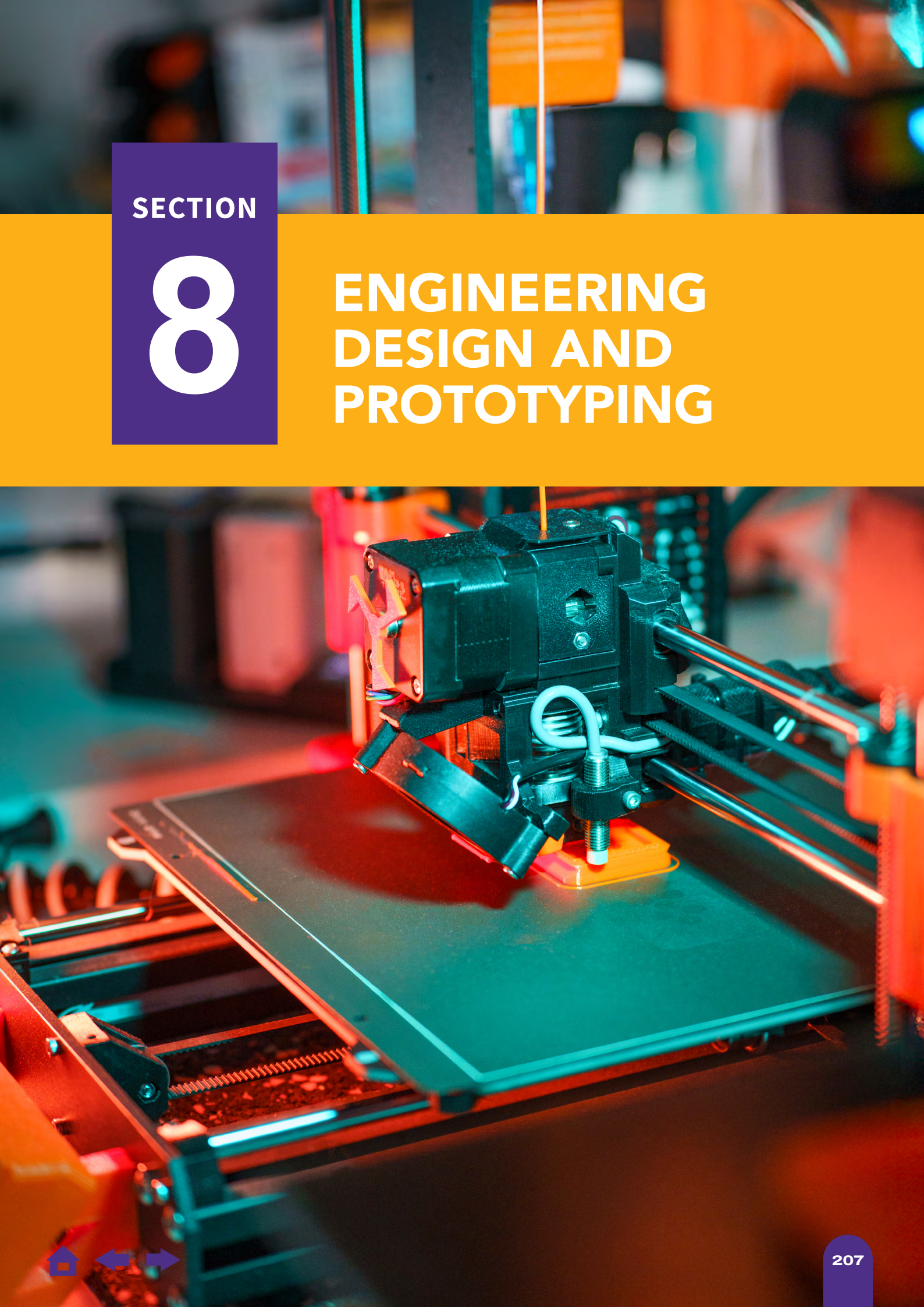
REVIEW QUESTIONS

1. Your team has designed a prototype for a collapsible shopping bag made from recycled materials. During testing, it struggles to hold heavy items. What steps would you take to validate and improve your prototype?
2. After testing your self-watering plant pot prototype, the soil remains dry. What does this indicate, and how would you validate the root cause?
3. Your group built a prototype mobile phone holder for desks. It tips over when a large phone is placed on it. What test methods would you use to validate the holder's stability?
4. A prototype solar-powered flashlight dims quickly during use. How would you test and validate if the problem is in the solar panel or the battery?
5. After testing a hand-made air freshener dispenser, users report it sprays inconsistently. What would you do to validate this feedback and improve the prototype?
6. You created a lightweight stool prototype for students. After testing, it cracks when a person over 70kg sits on it. How do you validate its weight limit and ensure it's safe?
7. Your group is testing a rainwater collection system made from plastic bottles. After a week, there's leakage from the joints. What validation approach would confirm the cause?
8. During testing of your prototype pencil case with a built-in sharpener, users complain that it damages pencils. How would you collect and validate user feedback?
9. A prototype alarm system for detecting open doors fails during night tests. How can you validate the reliability of its sensors?
10. Your team designed a foldable laptop stand. During tests, hinges loosen after repeated folding. How do you validate the durability and lifespan of your prototype?
11. Your group created a prototype of a cardboard bookshelf, but during testing, it bends and collapses when books are placed on the top shelf.

Analyse the failure and suggest a remedy.

12. A prototype automatic hand sanitiser dispenser often leaks after use. What could be causing the failure, and how would you fix it?
13. After testing a prototype portable phone charger powered by solar, users report it charges devices too slowly. Identify the possible failure point and propose a solution.
14. You tested a low-cost water filter prototype made from sand and charcoal, but it fails to remove visible particles. What is likely wrong and how can it be corrected?
15. A prototype wind-powered phone charger fails to generate enough power during testing. Analyse the failure and recommend a solution.
16. A smart bin prototype with a motion sensor lid fails to open at the right time. What could be the cause and how can you fix it?
17. After classroom testing, your solar cooker prototype does not heat water to boiling point. Identify and analyse the failure, then suggest a practical remedy.

18. A mechanical toy car prototype moves unevenly and stops frequently. Analyse the failure and suggest an improvement.
19. Your group built a low-cost smart lamp with an ambient light sensor, but it doesn't respond correctly to changes in light. What is the issue, and how can it be fixed?
20. A prototype schoolbag with built-in back support collapses when loaded with books. Evaluate the problem and propose a remedy.

A close-up photograph of a 3D printer's extruder head. The head is black and metallic, with a white filament being fed into it. It is positioned over a flat, dark-colored build plate. The printer's frame is visible in the background, with orange and black components. The lighting is dramatic, with strong highlights and shadows, giving it a high-tech, industrial feel.

SECTION

8

ENGINEERING DESIGN AND PROTOTYPING

RAPID PROTOTYPING

INTRODUCTION

The focus of this section is to guide you to be able to translate the content of a schematic diagram into a breadboard circuit implementation. Making the leap from a theoretical schematic to a functional physical circuit is a crucial ability in electronics. This procedure entails deciphering a schematic diagram, designing and putting the circuit together on a solderless breadboard, and carrying out extensive testing to ensure its functioning. You will understand that before committing to permanent designs, bread boarding is perfect for prototyping, testing, and debugging. Electronic components are mechanically supported and electrically connected by printed circuit boards (PCBs), which are thin boards composed of insulating material with conductive paths carved or printed onto them.

KEY IDEAS

- **Breadboard Implementation and Circuit Interpretation:** You should develop the ability to accurately interpret a schematic diagram and translate it into a functional breadboard circuit. This foundational step enhances understanding of component layout, circuit functionality, and the physical relationship between elements, laying the groundwork for prototype development and testing.
- **Design Transfer and CAD/CAM Proficiency:** Prototyping extends beyond breadboards into professional-level PCB design. You must convert schematic diagrams into PCB layouts using CAD tools, then fabricate and assemble these circuits using CAM processes. This exposes you to real-world design workflows and industry-relevant skills in electronics manufacturing.
- **Design Reflection and Continuous Improvement:** The prototyping process should foster a mindset of iteration. You must document all outcomes, including unexpected behaviours or failures, and use these insights to refine their design. Reflection, peer feedback, and testing data should drive continuous improvement, building resilience and problem-solving capacity in you.
- **Functional Testing and Performance Verification:** Once assembled, both breadboard and PCB prototypes should be tested under various operational conditions. You must evaluate whether the circuit meets the intended specifications for functionality, efficiency, and safety. Emphasis should be placed on accurate measurement, interpretation of results, and use of diagnostic tools.

CONVERT A GIVEN SCHEMATIC DIAGRAM INTO A BREADBOARD CIRCUIT IMPLEMENTATION AND PROCEED TO ASSEMBLE COMPONENTS ON THE SOLDERLESS BREADBOARD AND TEST THE CIRCUIT.

In electronics, being able to turn a circuit diagram into a real, working circuit is a very important skill. You will learn how to read the diagram, build the circuit using a solderless breadboard, and test it to make sure everything works correctly. A breadboard is great for trying out your ideas and fixing any issues before making a final version.

1. Understanding the Circuit Diagram

A circuit diagram (also called a schematic) shows how electronic components are connected. Each part is shown using a symbol. Some common components you will see include:

- Resistors – control the flow of electric current
- Capacitors – store and release electric energy
- LEDs – light up when current flows through
- Transistors – act like switches or amplifiers
- Power sources – like batteries or power adapters
- ICs (Integrated Circuits) – small chips that do special tasks
- Wires – connect all the parts together

Reading and understanding this diagram helps you build and test your own electronic circuits.

Each symbol is labelled with a reference designator (e.g., R1, D1) and value (e.g., 1k Ω).

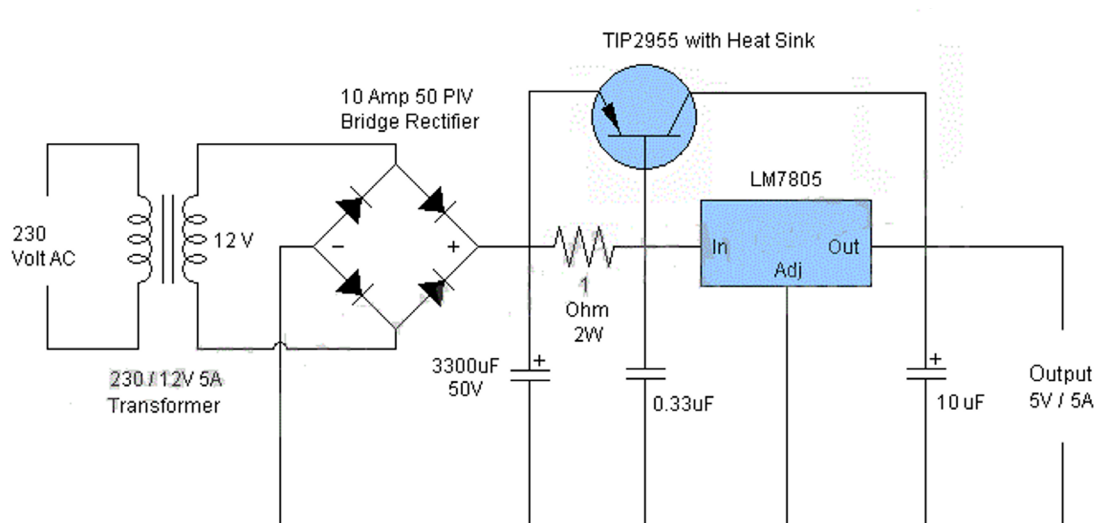


Figure 8.1: Schematic Diagram of a Power Supply Circuit

2. Key Skills

Before you build the circuit, there are some important skills to learn:

- Recognise components and read their values (like the resistance of a resistor).
- Understand how components connect and how the current flows through the circuit.
- Know where to connect the power supply and ground (GND) so the circuit gets electricity safely.

3. Plan the Breadboard Layout

A solderless breadboard has rows and columns of tiny holes (sockets) to plug in components and wires. Here is how it works:

- The horizontal rows at the top and bottom (called power rails) are connected across.
- The vertical columns in the middle are connected in groups of five holes, and there is a gap in the centre where ICs, or chips, are usually placed.

4. Planning Tips

Planning carefully makes your circuit easier to build and fix:

- Start with the power connections (connect +V and GND).
- Place large parts like ICs first so you can build around them.
- Try not to cross wires—this keeps things neat and easier to troubleshoot.
- Use jumper wires in different colours (e.g., red for power, black for ground) to stay organised.

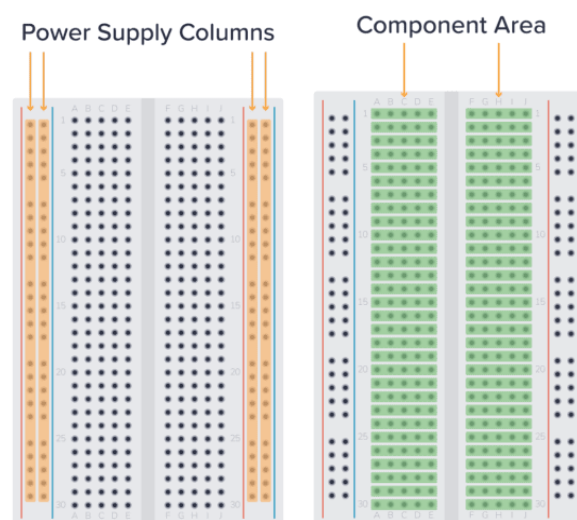


Figure 8.2: Pictures of Solderless Breadboard Interconnections

5. Convert the Schematic to Breadboard

Follow these steps to convert the schematic:

Step 1: Place the IC or central component

Align it across the centre gap of the breadboard so each pin has a separate row.

Step 2: Add passive components

Insert resistors, capacitors, etc., in correct locations as per the schematic.

Step 3: Connect using jumper wires

- a. Use wires to replicate schematic connections.
- b. Pay close attention to pin numbers on ICs and transistor orientations.

Step 4: Power the breadboard

- a. Connect power rails to the appropriate voltage source (e.g., 5V or 9V).
- b. Use a regulated supply if needed.

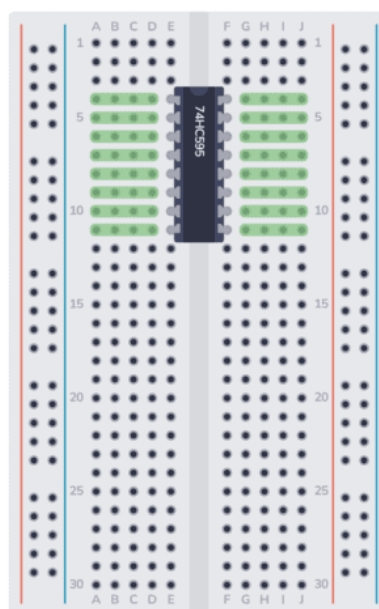


Figure 8.3: A picture of how to connect an IC on the breadboard

6. Test the Circuit

- a. Before applying full power. Visual Inspection:
 - i. Check for loose connections.
 - ii. Confirm component values and orientation (especially for LEDs, diodes, and ICs).
- b. Power-On Testing
 - i. Apply power gradually using a bench power supply with current limiting.
 - ii. Monitor for signs of overheating or short circuits.
 - iii. Measure voltages at key points using a multimeter.

- c. Functional Testing
- i. Observe expected output (e.g., LED blinking, sensor response, output voltage).

ii. Use an oscilloscope or logic analyser for digital signals, if needed.

Practical Example: LED Blinker Circuit Using 555 Timer Components list

Component	Value/Type	Quantity	Notes
555 Timer IC	NE555	1	Timer IC core
Resistor R1	1 kΩ	1	Controls charge rate
Resistor R2	100 kΩ	1	Sets timing
Resistor R3	470 Ω	1	Limits current to LED1
Resistor R4	470 Ω	1	Limits current to LED2
Capacitor C1	1 μF	1	Timing capacitor
Capacitor C2	10 nF	1	Bypass capacitor
LED1, LED2	Red (or any colour)	2	Visual indicators
Switch S1	Pushbutton (NO)	1	Optional trigger
Power Supply	9V battery	1	Circuit power source
Breadboard & Wires	–	–	For assembly

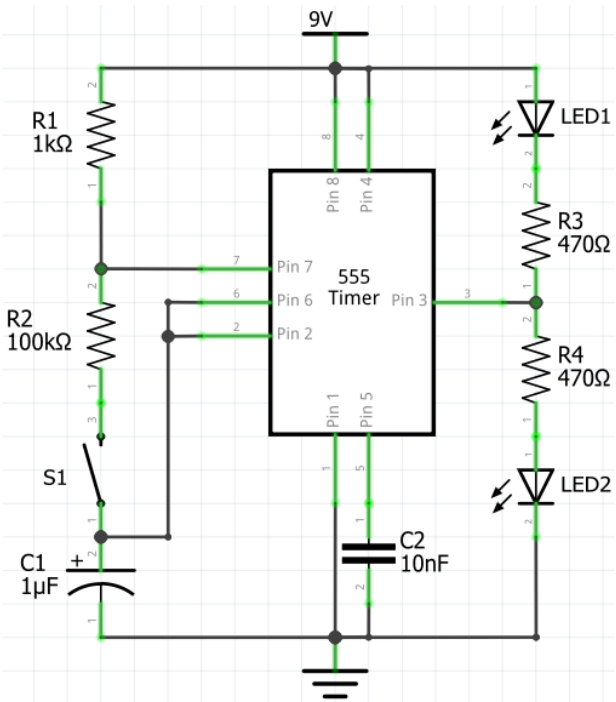


Figure 8.4: A circuit diagram of an LED Blinker Circuit Using a 555 Timer

BREADBOARD ASSEMBLY GUIDE

Step-by-step Wiring

1. Power Rails
 - a. Connect the +9V from the battery to the breadboard's + rail.
 - b. Connect GND to the breadboard's – rail.
2. Place the 555 Timer: Insert the 555 timer across the middle trench of the breadboard (pins on both sides).
3. Connect Pins on the 555 Timer
 - a. Pin 1 (GND) → GND rail
 - b. Pin 8 (Vcc) → +9V rail
 - c. Pin 4 (Reset) → +9V rail
 - d. Pin 5 (Control Voltage) → Connect capacitor C2 (10nF) between pin 5 and GND
 - e. Pin 2 (Trigger) & Pin 6 (Threshold) → Tie together and to junction of R2 and C1
 - f. Pin 3 (Output) → Goes to both R3 and R4 (which go to LEDs)
4. Add Resistors and a Capacitor for Timing
 - a. R1 (1kΩ) → Between pin 7 and Vcc
 - b. R2 (100kΩ) → Between pins 6 and 7
 - c. C1 (1μF) → Between pin 6 and GND
5. Add LEDs
 - a. R3 (470Ω) → From pin 3 to anode of LED1
 - b. R4 (470Ω) → From pin 3 to anode of LED2
 - c. Cathodes of both LEDs → GND
6. (Optional) Add Pushbutton S1: Between the junction of R2 and C1 and GND – used to restart the cycle if manually triggered.

Final Testing Procedure

Steps for Functional Testing

1. Power ON the circuit by connecting a 9V battery or regulated adapter.
2. Observe the LEDs
 - a. LEDs should blink alternately at a fixed rate.
 - b. The timing of the blinking is controlled by R1, R2, and C1.
3. Test the pushbutton (S1): Pressing it may reset the cycle depending on how it is wired. If you added S1 to control triggering, check LED1/2 response.

4. Use a multimeter: Measure voltage at pin 3. It should alternate between $\sim 0V$ and $\sim 9V$.
5. Troubleshooting: If no blinking occurs
 - a. Check the orientation of the 555 timer.
 - b. Make sure LEDs are not reversed.
 - c. Verify capacitor polarity (C1).
 - d. Confirm resistor and capacitor values.

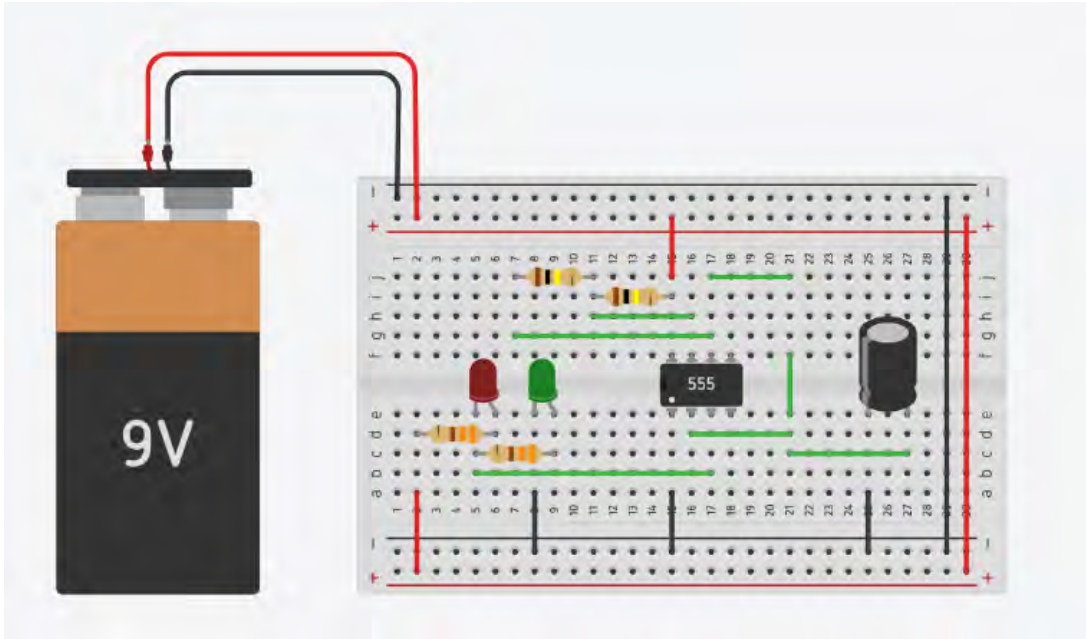


Figure 8.5: Picture of LED Blinker Circuit Using 555 Timer

Conclusion

Successfully implementing a schematic onto a breadboard requires understanding component symbols, correct placement, clean wiring, and methodical testing. This hands-on process builds foundational skills in prototyping, circuit debugging, and electronic design validation.

*Activities – choose **THREE** of the following activities 8.1 – 8.9 (the rest are optional)*

Activity 8.1 LED Indicator Circuit

Build and test a simple LED circuit from a schematic.

Steps

1. Interpret the schematic showing an LED in series with a resistor and a power source.
2. Assemble the circuit on the breadboard.
3. Use a multimeter in continuity mode to check connections.
4. Measure the voltage across the LED and resistor.

Questions

1. Is the LED lighting as expected?
2. Are voltage readings matching your calculations?
3. What could be causing any discrepancies?

Activity 8.2 Series Resistor Voltage Divider

Build a voltage divider and verify voltages.

Steps

1. Read the schematic showing two resistors in series.
2. Assemble and power the circuit.
3. Measure voltage at the midpoint.

Questions

1. Does the measured voltage match theoretical values?
2. If not, where are the errors?

Activity 8.3 Parallel LED Circuit

Construct a circuit with two LEDs in parallel.

Steps

1. Follow the schematic for parallel LED wiring.
2. Build on the breadboard.
3. Verify each branch's continuity and voltage.

Questions

1. Do all LEDs light equally?
2. How do voltage readings compare across each LED?

Activity 8.4 Push-Button Controlled LED

Assemble a simple button-switch circuit with an LED.

Steps

1. Interpret the switch schematic.
2. Assemble the circuit.
3. Use a continuity test while pressing the button; measure LED behaviour.

Questions

1. Does the LED respond to the button as expected?
2. Are connections solid and reliable?

Activity 8.5 Light Sensor with LDR

Build an LDR-based light detection circuit.

Steps

1. Read the circuit showing the LDR-resistor voltage divider.
2. Build the circuit on a breadboard.
3. Measure voltage with light and in darkness.

Questions

1. How does voltage change with light levels?
2. Does it match theory?

Activity 8.6. Transistor Switch

Build an LED-controlled transistor switch.

Steps

1. Follow the schematic wiring of the transistor base, emitter, and collector.
2. Power the circuit and measure when the LED turns on.
3. Use a multimeter to check voltage at transistor terminals.

Questions

1. Does the LED turn on when expected?
2. Are voltage levels consistent with operation?

Activity 8.7 Capacitor Charging Circuit

Assemble and observe a resistor-capacitor charging circuit.

Steps

1. Build per the diagram.
2. Apply power and measure voltage across the capacitor over time.

Questions

1. Does voltage rise over time as expected?
2. Is the charging time consistent with calculations?

Activity 8.8 Alarm with Sensor

Construct a basic alarm circuit activated by a switch.

Steps

1. Interpret the schematic indicating the switch and alarm connection.
2. Build and test the circuit.
3. Use a multimeter to verify the connection only activates with the switch.

Questions

1. Does the circuit remain inactive until triggered?
2. Are there unintended activations?

Activity 8.9 Temperature Sensor Setup

Assemble an LDR or thermistor-based sensor circuit.

Steps

1. Wire the voltage divider following the schematic.
2. With heat applied, measure voltage change.

Questions

1. Does voltage vary with temperature/light as expected?
2. Is the circuit behaving correctly?

CONVERTING A GIVEN ELECTRONIC CIRCUIT INTO A PCB AND PRODUCING A FUNCTIONING PCB BOARD USING CAD AND CAM TOOLS

A Printed Circuit Board (PCB) is a flat board that holds and connects electronic parts. It has special paths made of metal that allow electricity to flow between the components, helping them work together.

Overview of the PCB Design and Production Process

The process of converting a schematic into a working PCB can be broken down into five main stages:

Step 1: Draw the Electronic Schematic

- a. Use a CAD (Computer-Aided Design) tool like KiCad, EasyEDA, Proteus, Fritzing, or Eagle.
- b. Place and connect all components in a logical diagram format.
- c. This stage ensures the logical correctness of the circuit.

Step 2: Assign Component Footprints

- a. Each symbol used in the schematic must have a footprint (physical layout).
- b. Example: A resistor in the schematic must be matched with the correct footprint that represents its size and pin layout.

Step 3: Design the PCB Layout

- a. Arrange the footprints on a virtual board.
- b. Route the copper traces to make electrical connections between components.
- c. Add vias (holes), pads, labels, and mounting holes.
- d. Follow Design Rules (e.g., spacing, minimum trace width).
- e. Run a DRC (Design Rule Check) to catch layout errors.

Step 4: Generate CAM Files

- a. Use the CAD software's CAM (Computer-Aided Manufacturing) module to export files like:
 - i. Gerber files for copper layers, silkscreen, and solder mask.
 - ii. Drill files for vias and holes.
- b. These files are the standard format used by PCB manufacturers.

Step 5: Fabricate and Assemble the PCB

- a. Send the Gerber and drill files to a PCB fabrication service (e.g., JLCPCB, PCBWay) or use an in-school milling machine.
- b. Once the PCB is made, solder all components in place.
- c. Test the assembled PCB with tools like a multimeter or oscilloscope to verify functionality.

Example: Temperature-Controlled Fan System

Circuit Goal: A system that turns on a fan when the temperature exceeds a set threshold.

Components

1. **BT1** – 9V Battery
2. **RV1** – Variable Resistor (10k Potentiometer)
3. **R1** – 4.7k Ω Resistor
4. **R2** – 330 Ω Resistor
5. **TH1** – NTC Thermistor (temperature-sensitive resistor)
6. **IC1** – LM741 Operational Amplifier (Op-Amp)
7. **Q1** – BC547 NPN Transistor

8. **D1** – 1N4007 Diode (for flyback protection)
9. **M1** – DC Fan
10. **PCB Board, jumper wires, connectors**

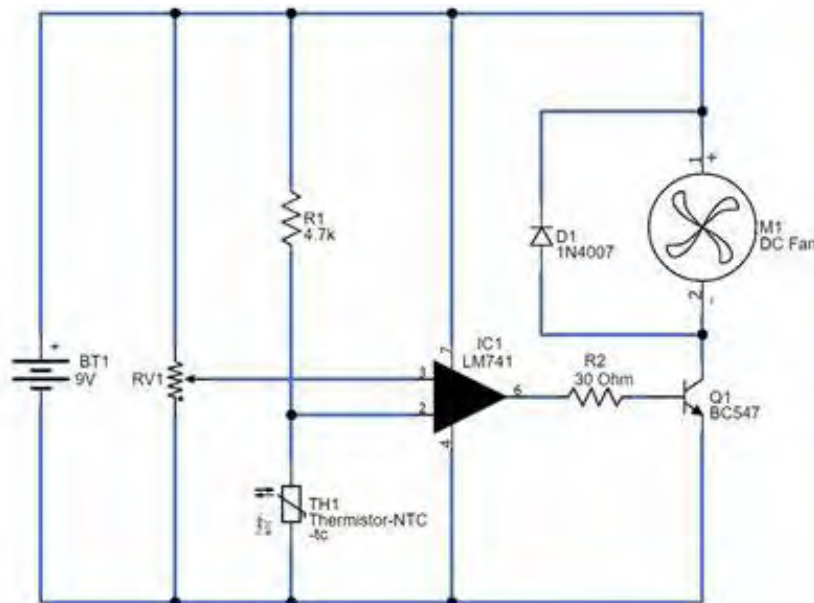


Figure 8.6: Circuit diagram of DC Fan Circuit

1. Process Summary (Working Principle)
 - a. Sensing Temperature: The thermistor (TH1) changes its resistance with temperature. As temperature increases, its resistance decreases (since it's an NTC type).
 - b. Voltage Divider: The thermistor and potentiometer form a voltage divider, providing an input voltage to the non-inverting terminal of the LM741 op-amp.
 - c. Comparison (Op-Amp): The op-amp compares the voltage from the voltage divider with a reference voltage. When the temperature rises above a certain threshold, the output of the op-amp goes high.
 - d. Transistor Activation: The high output from the op-amp turns on the NPN transistor (BC547), which allows current to flow through the fan, thus powering it on.
 - e. Flyback Diode Protection: The 1N4007 diode protects the transistor from voltage spikes generated by the inductive load (DC fan).
2. Common CAD Tools for PCB Design
 - a. Proteus Design Suite – Great for simulation and PCB design (easy for beginners).
 - b. KiCad – Open-source, powerful for schematic capture and PCB layout.
 - c. Eagle (by Autodesk) – Popular tool with schematic + PCB layout and 3D view.
 - d. Altium Designer – Industry-grade PCB design software with rich features.
 - e. EasyEDA – Cloud-based tool; integrates with LCSC for component sourcing.
 - f. Fritzing – Beginner-friendly for prototyping and education.

3. Benefits of Using CAD/CAM Tools in PCB Design

- a. Accuracy and Precision: Ensures correct component placement and routing.
- b. Design Simulation: Helps verify circuit function before physical implementation.
- c. Faster Prototyping: Rapid generation of schematics and PCB layouts.
- d. 3D Visualisation: View the final product in 3D to catch design flaws.
- e. Manufacturing Integration: Directly export Gerber files for fabrication.
- f. Documentation: Automatic generation of BOM (Bill of Materials) and assembly diagrams.
- g. Error Detection: DRC (Design Rule Check) reduces the risk of design errors.

4. Safety and Best Practices

- a. Electrical Safety
 - i. Double-check polarity for all components, especially the diode and transistor.
 - ii. Use a current-limited power supply during testing.
 - iii. Ensure proper insulation of wires to prevent short circuits.
- a. Component Handling:
 - i. Handle ICs with care to avoid ESD damage.
 - ii. Use proper heat dissipation (heatsinks or ventilation) for the fan/transistor if needed.
- b. PCB Design Best Practices:
 - i. Use thicker traces for power lines.
 - ii. Keep ground and power planes separated.
 - iii. Use bypass capacitors near ICs to reduce noise.
 - iv. Label all components clearly on the silkscreen layer.
 - v. Run a DRC and ERC (Electrical Rule Check) before exporting files.
- c. Environmental Best Practices:
 - i. Recycle non-functional PCBs properly.
 - ii. Avoid lead-based solder where possible (use RoHS-compliant alternatives).
 - iii. Wear eye protection during soldering.

Activities – choose *THREE* of the following activities 8.10 – 8.19

- One from 8.11, 8.13, 8.14, 8.16
- One from 8.15, 8.17, 8.18
- One from 8.12, 8.19
- **AND** 8.20 (four in total - the rest are optional)

Activity 8.10 USB Phone Charger Circuit

Design and produce a PCB for a 5V USB phone charger.

Steps

1. Study the schematic of a USB phone charger.
2. Use KiCad to create a single-layer PCB layout.
3. Convert the layout to Gerber files for CAM.
4. Produce the PCB using the prototyping machine.
5. Solder the components onto the PCB.
6. Test with a multimeter and a phone.

Questions

1. Why is a voltage regulator important in this circuit?
2. What do you observe when you measure the output voltage?
3. How would you troubleshoot if the charger doesn't work?

Activity 8.11 LED Flasher Circuit

Convert a simple blinking LED circuit into a PCB.

Steps

1. Assemble the circuit on a breadboard and test it.
2. Create the schematic in KiCad and design the layout.
3. Export Gerber files.
4. Manufacture the PCB.
5. Assemble and solder components.
6. Test for functionality and blinking pattern.

Questions

1. What would happen if one LED were soldered in reverse?
2. How did the layout affect the ease of soldering?
3. What are common mistakes in PCB design?

Activity 8.12 Touch-Activated Switch

Design and implement a PCB for a touch sensor switch.

Steps

1. Review and understand the schematic.
2. Simulate in software if possible.

3. Create a PCB layout using KiCad.
4. Fabricate the board.
5. Solder and test the circuit.
6. Connect to an LED or buzzer to see the output.

Questions

1. How does the touch circuit detect human touch?
2. What tools did you use to verify the connections?
3. If the sensor doesn't respond, where would you start troubleshooting?

Activity 8.13 Water Level Indicator

Produce a PCB for a water tank level indicator using LEDs.

Steps

1. Discuss the real-world application of water indicators.
2. Create a schematic and layout in CAD.
3. Export to CAM and produce a PCB.
4. Solder components based on the layout.
5. Test with a water container.

Questions

1. Which LED lights up first and why?
2. How did you test continuity on the board?
3. What would happen if the probes corroded?

Activity 8.14 Emergency Light Circuit

Create a PCB for a rechargeable LED emergency light.

Steps

1. Understand how the circuit stores and provides backup light.
2. Design the layout using KiCad.
3. Produce the PCB.
4. Assemble and test with a dark room setup.

Questions

1. How did you ensure charging and lighting sections don't conflict?
2. What is the function of the diode in the circuit?

Activity 8.15 Mini FM Transmitter

Design a PCB for a simple FM transmitter.

Steps

1. Learn the schematic and its transmission principles.
2. Design PCB layout.
3. Produce, assemble and test the range using a radio.

Questions

1. What components affect the frequency range?
2. What safety precautions should you consider?

Activity 8.16 Digital Dice Project

Create a PCB for an electronic dice using ICs and LEDs.

Steps

1. Breadboard the circuit first.
2. Translate to KiCad and design the PCB.
3. Fabricate, assemble, and test the roll button functionality.

Questions

1. What determines the output pattern?
2. What's the benefit of a PCB over a breadboard in this project?

Activity 8.17 Temperature Monitor with Thermistor

Design a PCB for a basic temperature alert circuit.

Steps

1. Build and test on a breadboard.
2. Create a layout in KiCad.
3. Manufacture and assemble the PCB.
4. Heat or cool the thermistor to test output.

Questions

1. What role does the op-amp play?
2. How would you change the threshold?

Activity 8.18 Simple Power Supply PCB

Design a PCB for a 12V to 5V converter.

Steps

1. Understand and test the circuit on a breadboard.
2. Design PCB layout.
3. Produce, solder, and test voltage conversion.

Questions

1. How do you confirm correct voltage output?
2. What happens if the input exceeds the regulator limit?

Activity 8.19 Timer-Based Garden Watering System

Design and build a PCB for an automatic watering timer.

Steps

1. Simulate the timer and relay behaviour.
2. Design and fabricate the PCB.
3. Connect to water pump and test in the garden.

Questions

1. What issues might occur with the relay?
2. How would you improve the system?

This final activity (8.20) wraps all the learning from Y1-Y3 together. This will help you recap all you have learnt under this section.

Activity 8.20 From Circuit Design to Functional Prototype

Materials Needed

- Printed schematic diagrams
- Breadboards
- Electronic components (resistors, capacitors, ICs, LEDs, transistors, etc.)
- Jumper wires
- Power supply or batteries
- Computer with CAD software (e.g., EasyEDA, KiCAD, Tinkercad, Fusion 360)
- PCB fabrication tools or access to PCB production service
- 3D printer and filament (e.g., PLA or ABS)
- Safety gear (gloves, goggles)

- Laser cutter (if available)
- Casting materials (optional, if doing casting)

Steps

Part 1: Breadboard Prototyping from a Schematic

- 1. Review the Schematic Diagram**
 - a. Identify all components and their values.
 - b. Understand connections and power supply.
- 2. Plan the Breadboard Layout:** Sketch the layout on paper or use simulation software.
- 3. Assemble the Circuit**
 - a. Insert components and jumper wires on the breadboard.
 - b. Double-check connections before powering the circuit.
- 4. Test and Troubleshoot**
 - a. Power up the circuit and observe behaviour.
 - b. Record any faults and suggest corrections.

Part 2: PCB Design and Fabrication

- 5. Convert the Schematic into a PCB Design:** Use a CAD tool (e.g., EasyEDA) to draw the circuit layout.
- 6. Route Tracks and Generate Gerber Files:** Use auto/manual routing to complete the PCB layout.
- 7. Simulate and Verify:** Simulate the design to ensure correct function.
- 8. Fabricate the PCB:** Use in-house CAM tools or send to a fabrication service.
- 9. Assemble and Test the PCB**
 - a. Solder components onto the finished PCB.
 - b. Test the PCB to verify functionality.

Part 3: Learn Rapid Prototyping Principles

- 10. Mini-Lecture and Demo**
Discuss the principles, materials, and uses of:
 - a. 3D printing (e.g., FDM process)
 - b. PCB production
 - c. Casting
 - d. Laser cutting
- 11. Group Discussion:** Brainstorm examples of how each method is applied in engineering and manufacturing.

Part 4: CAD Design and 3D Printing

12. **Design a Simple Enclosure or Model in CAD:** Create a 3D design using Tinkercad or Fusion 360.
13. **Prepare the File for Printing:** Convert the file to STL format and slice it using Cura or similar software.
14. **Configure and Start the 3D Printer**
 - a. Set up print settings (layer height, speed, infill).
 - b. Load filament and begin printing.
15. **Post-Processing and Reflection**
 - a. Remove supports and clean the printed part.
 - b. Reflect on challenges and propose improvements

Questions

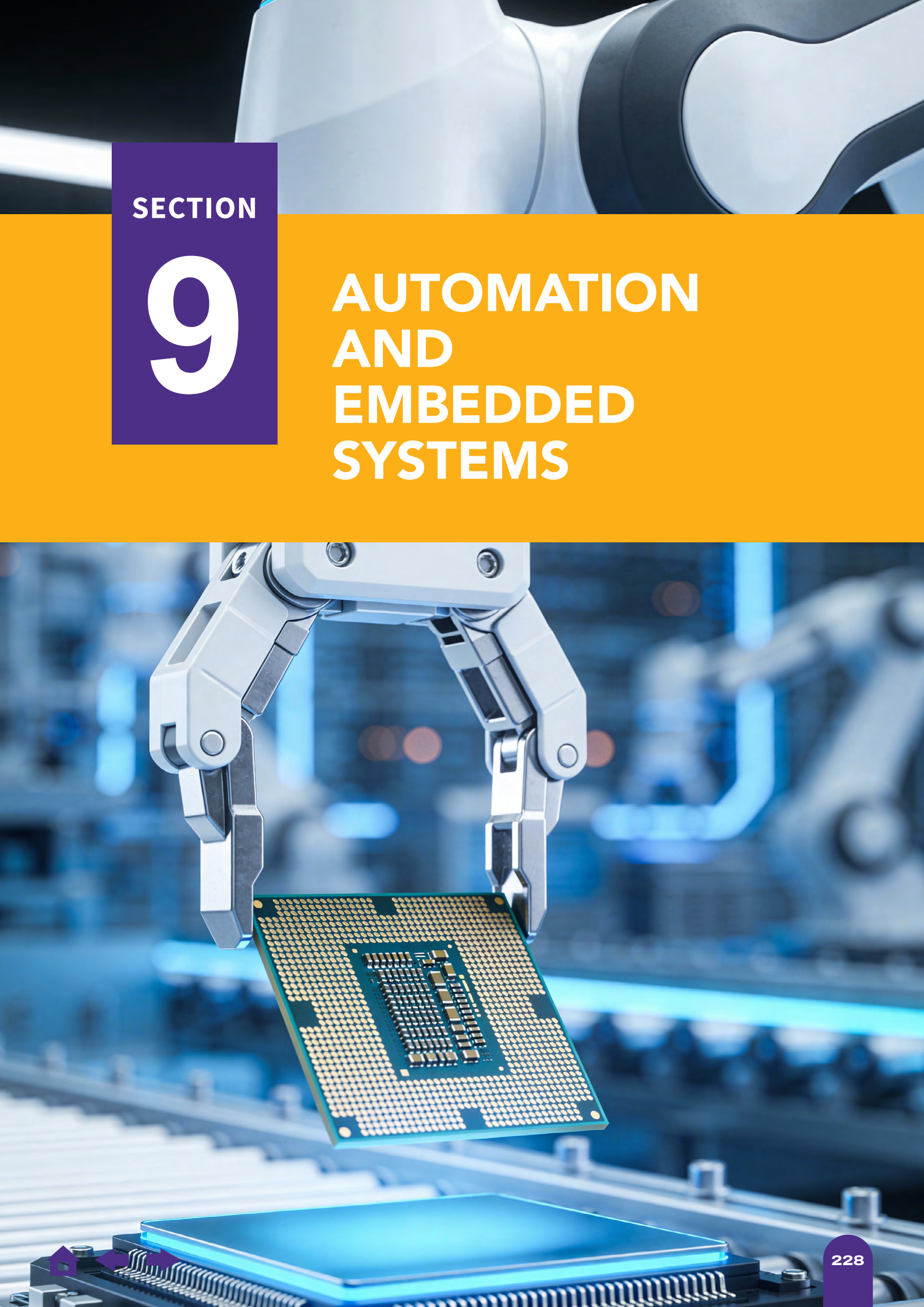
1. What challenges did you face while building the breadboard circuit?
2. How does PCB design differ from breadboard prototyping?
3. Which rapid prototyping method would be best for producing a phone casing? Why?
4. What design changes would improve the 3D-printed model you created?

EXTENDED READING

- Bogatin, E. (2021). Bogatin's Practical Guide to Prototype Breadboard and PCB Design. United Kingdom: Artech House.
- May, V. V. (2015). 3-D Engineering: Design and Build Your Own Prototypes. United States: Nomad Press.

REVIEW QUESTIONS

1. You are given a schematic diagram of a basic LED circuit with a 220Ω resistor and a 9V battery. Describe how you would transfer this schematic onto a solderless breadboard.
2. After assembling a simple LED circuit, the LED does not light up. List at least three possible reasons and how you would test for each using a digital multimeter.
3. You have a schematic with a 555 timer IC used in astable mode. How would you position the IC on the breadboard to ensure correct pin connections?
4. You are using a multimeter to test a circuit and find no voltage across a resistor. What could this indicate about your breadboard circuit, and what should you check?
5. Given a schematic with both series and parallel connections of LEDs and resistors, how do you identify and implement the parallel connections on the breadboard?
6. You are asked to test a voltage divider made of two resistors ($R1 = 1k\Omega$, $R2 = 1k\Omega$) powered by 9V. What voltage should you expect at the midpoint, and how would you measure it?
7. Your schematic uses a capacitor to smooth voltage fluctuations. Where and how would you place this capacitor on the breadboard?
8. If the schematic calls for a transistor to control an LED with a switch, what is the correct sequence for connecting the emitter, base, and collector on the breadboard?
9. You assembled a breadboard circuit, but multiple LEDs are not turning on even though the power is supplied. What systematic steps would you follow to identify the fault?
10. How do you modify your breadboard implementation if the schematic diagram is updated to include a push-button to control an LED?
11. You are given a schematic diagram of an LED flasher circuit. What is the first step you would take to begin designing a PCB using a CAD tool?
12. After entering your schematic into the CAD software, the software shows a “missing connection” warning. What should you do?
13. You have successfully created a schematic in the CAD tool. What do you do next before converting it to a PCB layout?
14. While converting your schematic to PCB layout, you see overlapping components. What action should you take?
15. You are routing tracks on the PCB. Why is it important to keep signal tracks short and avoid sharp 90-degree angles?
16. Your CAD software gives you the option to auto-route the PCB. What should you consider before using it?
17. You have finished routing the PCB. What should you do before generating the Gerber files?
18. After generating the Gerber files from your CAD design, how are these files used in the CAM process?
19. During the PCB etching process in a CAM lab, what safety precaution should you observe?
20. After producing the PCB and soldering the components, the circuit does not work. What troubleshooting step should you take first?

The image is a book cover for 'Section 9: Automation and Embedded Systems'. It features a background image of a robotic arm holding a microchip. The top half of the cover has a purple vertical band on the left containing the text 'SECTION 9' and an orange horizontal band on the right containing the title 'AUTOMATION AND EMBEDDED SYSTEMS'. The bottom half of the cover shows a close-up of a robotic arm's gripper holding a green microchip with gold pins. The background is a blurred industrial setting with blue lighting. In the bottom left corner, there are small navigation icons: a house, a double arrow, and a single arrow. In the bottom right corner, there is a purple circle containing the page number '228'.

SECTION

9

AUTOMATION AND EMBEDDED SYSTEMS

AUTOMATION TECHNOLOGIES AND EMBEDDED SYSTEMS

INTRODUCTION

This section exposes you to the characteristics of general industrial automation control devices and implement simple automated system. Industrial automation systems are used to control machines and processes with minimal human intervention by using mechanical, electrical, and electronic components. You will understand that Programmable Logic Controller (PLC) is a rugged, digital computer used for industrial automation to monitor inputs, make logic-based decisions, and control outputs. An embedded system is a combination of hardware and software designed to perform a specific, dedicated function within a larger system. Skills you need to develop in this section are read and interpret circuit/control diagrams, wire and test basic automation circuits, identify and use common automation devices, think logically and troubleshoot errors and apply safety procedures during implementation.

KEY IDEAS

- **Designing and Implementing Simple Industrial Automation Systems:** Basic automated systems can be designed and constructed by integrating motors, sensors, actuators, relays, switches, and fluid power components. These systems perform tasks such as sorting, conveying, or lifting based on specific design requirements using control logic and signal flow planning.
- **Designing Embedded Systems for Sensor and Actuator Control:** Embedded systems can be created using microcontrollers like Arduino or ESP32 to read sensor inputs and control actuators. These systems may include functionalities such as temperature regulation, motion detection, or automated lighting, based on programming logic that responds to input signals.
- **Programming and Integrating PLCs in Automation Systems:** PLCs can be programmed using ladder logic or function block diagrams and used to control sensors, actuators, motors, and relays in industrial setups. They enable real-time decision-making, timing, and sequencing in automated systems and are commonly applied in conveyor control, process monitoring, and machine automation.

DESIGN AND IMPLEMENTATION OF SIMPLE INDUSTRIAL AUTOMATED SYSTEMS USING A COMBINATION OF MOTORS, FLUID POWER SYSTEMS, SENSORS AND ACTUATORS, SWITCHES AND RELAYS BASED ON DESIGN REQUIREMENTS

Industrial automation systems are used to make machines and processes work automatically, using components like motors, sensors, switches, and controllers with very little need for people to control them directly.

1. Core Components

- a. Motors – These make things move (e.g., DC, AC, stepper motors)
- b. Fluid Power Systems – Use air (pneumatic) or liquid (hydraulic) to move things
- c. Sensors and Actuators – Detect things (e.g., heat, motion) or move things (e.g., solenoids)
- d. Switches and Relays – Help turn things on and off, either manually or automatically
- e. Controllers – These include devices like PLCs and Arduinos that control how the system works

2. System Design Approach

- a. Define the Design Requirements
 - i. What task should the system perform? (e.g., move a box from one place to another)
 - ii. What safety features are needed? (e.g., emergency stop)
 - iii. How can the system save energy?
- b. Select Components Based on Application
 - i. Motors – Based on how fast or strong the movement needs to be
 - ii. Sensors – Based on what kind of information you need (e.g., position, temperature)
 - iii. Actuators – Choose between pushing/pulling or turning movement
 - iv. Switches/Relays – Decide if you need manual control or automatic logic
 - v. Controller – Decide whether to use a PLC, relay logic, or an Arduino

3. Component Overview and Selection

- a. Motors
 - i. DC Motors – Good for small machines like robotic arms
 - ii. AC Motors – Used in fans, pumps, and bigger conveyor belts

- iii. Stepper Motors – Good for jobs needing precise movement, like in 3D printers
- b. Fluid Power
 - i. Pneumatics – Use air for fast movement (e.g., in packing machines)
 - ii. Hydraulics – Use liquid for heavy tasks (e.g., lifting heavy parts)
- c. Sensors and Actuators
 - i. Proximity Sensors – Sense if something is near (metal or non-metal)
 - ii. Temperature Sensors – Used in heaters and ovens
 - iii. Limit Switches – Detect the end of a movement
 - iv. Solenoids and Linear Actuators – Move things in a straight line
- d. Switches and Relays
 - i. Manual Switches – Pressed by a person
 - ii. Contactors – Turn motors on and off
 - iii. Relays – Help control high voltage safely and add simple logic

4. Design and Implementation Process

- a. Circuit/System Diagram
 - i. Use software like Proteus, AutoCAD Electrical, or FluidSIM
 - ii. Show how power, sensors, controllers, and actuators are connected
- b. Write the Control Logic
 - i. Use relay logic or ladder diagrams (for PLCs)
 - ii. Add commands like start/stop and safety rules
- c. Build Your Prototype
 - i. Assemble all the parts on a panel or breadboard
 - ii. Label everything clearly and wire it safely
- d. Test the System
 - i. Check if sensors are working and triggering the right actions
 - ii. Make sure motors and actuators move the way they should
 - iii. Add safety features and test them

Real-World Examples

Example 1: Automated Bottle Filling System

Design Requirements

1. Detect when a bottle is in position

2. Fill the bottle using a fluid pump
3. Stop after a certain volume
4. Move the filled bottle using a conveyor

Components Used

1. IR Sensor to detect the bottle
2. Solenoid Valve to control fluid flow
3. DC Motor Conveyor controlled via relay
4. Limit Switch to detect bottle exit
5. Arduino/PLC to control sequence

Implementation

1. IR sensor triggers filling when the bottle is detected
2. Valve opens for a fixed time or based on the flow sensor
3. After filling, the conveyor moves the bottle to the next station



Figure 9.1: A picture of the Automated Bottle Filling System

Example 2: Automated Sorting System

Design Requirements

1. Sort Red and Green Apples
2. Move apples
3. Divert to separate containers

Components Used

1. Inductive Sensor (colour detection)
2. Pneumatic Pusher or Servo Motor
3. DC Conveyor Motor
4. PLC or Arduino

Implementation

1. The conveyor brings the item to the detection point
2. Sensor detects if Red
3. Actuator pushes item into appropriate container
4. System loops continuously

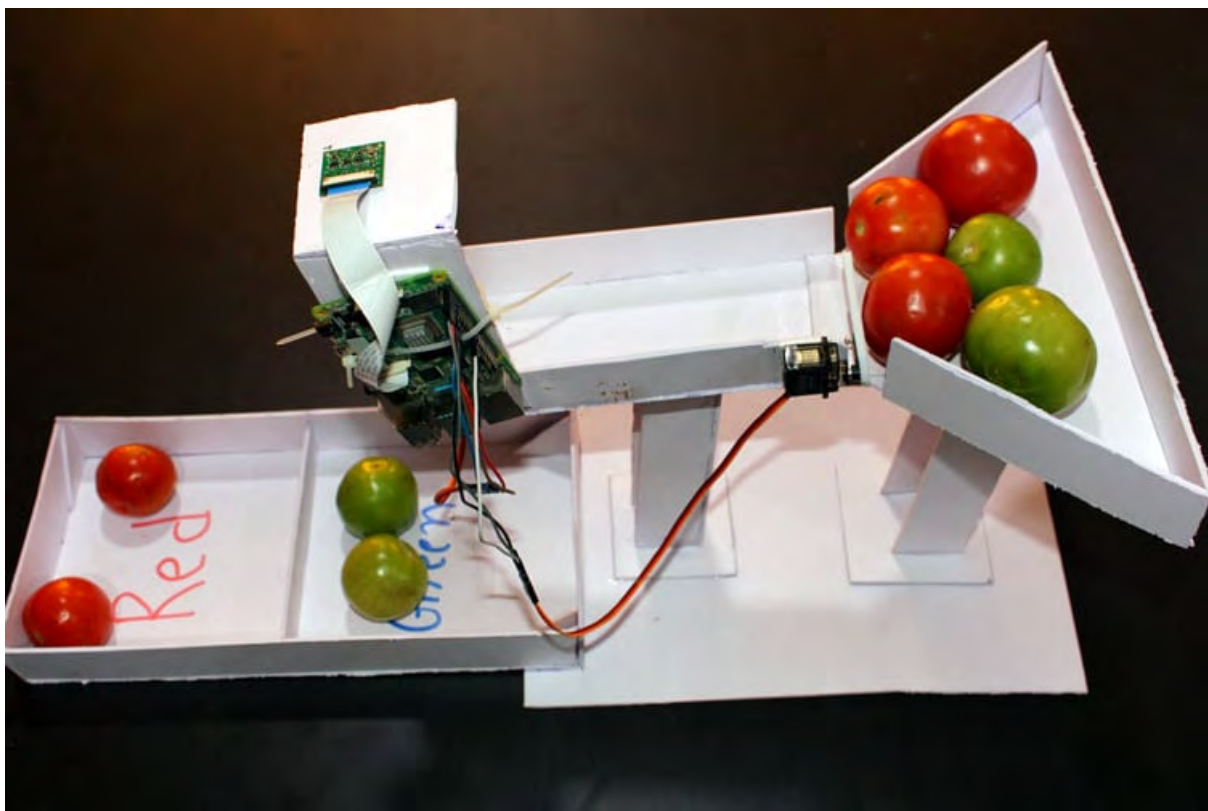


Figure 9.2: A picture of the Automated Sorting System

Activities – choose *THREE* of the following activities 9.1 – 9.9

- One from 9.1, 9.2, 9.3
- One from 9.4, 9.5, 9.6
- One from 9.7, 9.8, 9.9
- **AND** 9.10 (four in total - the rest are optional)

Activity 9.1 Conveyor Belt Sorting System

You are in a fruit packaging factory. The system automatically moves fruits on a conveyor, detects size, and sorts them into boxes. You will design and test a miniature version.

Steps

1. Form small groups.
2. Gather a DC motor, conveyor belt model, proximity sensor, relay module, and cardboard boxes.
3. Assemble the motor-driven belt.
4. Install the proximity sensor to detect objects on the belt.
5. Connect the relay module to control the motor.
6. Program the system so that when an object is detected, it stops briefly for sorting.
7. Test with different-sized items.
8. Document your wiring diagram and results.

Questions

1. How does the proximity sensor trigger the relay?
2. What would happen if the sensor failed?
3. How could this system be scaled for a real factory?

Activity 9.2 Automatic Bottle Filling Station

Factories fill thousands of bottles daily without spilling a drop. You will recreate a small version of this system.

Steps

1. In groups, collect a small pump, fluid container, fluid power tubing, IR motion sensor, relay, and empty bottles.
2. Mount the pump and connect it to the tubing.
3. Place the IR sensor where bottles will pass.
4. Program the relay to activate the pump only when a bottle is detected.
5. Test with water.
6. Record your wiring diagram and program flow.

Questions

1. Why is an IR sensor better than a button in this case?
2. How can you adjust the system to fill bottles faster?

Activity 9.3 Factory Gate Control System

Industrial gates open automatically for authorised vehicles. You'll build a model using sensors and actuators.

Steps

1. Gather a servo motor, proximity sensor, Arduino board, relay module, and model gate.
2. Attach the servo to the gate.
3. Program the sensor to detect a nearby object and trigger the servo.
4. Test with toy cars.
5. Document your design and results.

Questions

1. What role does the servo motor play?
2. How could you add security to this system?

Activity 9.4 Temperature-Controlled Fan System

Many factories need cooling systems that turn on automatically. You will design one using a thermal sensor.

Steps

1. Collect a DC fan, temperature sensor, relay, and Arduino.
2. Wire the temperature sensor to the Arduino.
3. Connect the fan via a relay.
4. Program the system to turn on the fan when the temperature exceeds a set value.
5. Test with a heat source (e.g., hairdryer).

Questions

1. Why is a relay needed here?
2. How can this be used in food storage facilities?

Activity 9.5 Automated Packaging Press

Factories often use presses to package items. You'll model one with a motor-driven pressing mechanism.

Steps

1. Gather a small DC motor, limit switches, a relay module, and a press frame (wood or cardboard).
2. Install the motor to drive the press arm.

3. Mount limit switches to stop movement at the top and bottom.
4. Program the system to cycle once per activation.
5. Test with soft items.

Questions

1. Why are limit switches important in automation?
2. How could this be made safer for workers?

Activity 9.6 Light-Activated Sorting Arm

In some plants, light sensors detect objects and direct them to different conveyors.

Steps

1. Collect a light sensor, servo motor, Arduino, relay, and model arm.
2. Connect the light sensor to detect brightness changes.
3. Program the servo to move items to a separate lane when the light level changes.
4. Test with objects casting shadows.

Questions

1. How does the sensor detect an object's presence?
2. Could this system work in the dark?

Activity 9.7 Automated Lift System

Lifts in warehouses move heavy items between floors automatically. You will build a simple model.

Steps

1. Gather a motor, pulley system, limit switches, and Arduino.
2. Build a small lift platform with string and a pulley.
3. Use limit switches to detect top and bottom positions.
4. Program the motor to move up or down based on a switch input.
5. Test with small loads.

Questions

1. Why are limit switches critical in lifts?
2. How could sensors improve safety here?

Activity 9.8. Factory Alarm System

Alarms warn of danger in industrial sites. You will make a model with sound and light indicators.

Steps

1. Collect a buzzer, LED light, smoke sensor (or simulate with a button), and Arduino.
2. Wire the buzzer and LED to the Arduino.
3. Program them to activate when smoke or a button is detected.
4. Test and document results.

Questions

1. Why use both light and sound alarms?
2. How could you link this to a central monitoring system?

Activity 9.9 Pneumatic Press Simulation

Fluid power systems like pneumatics are common in manufacturing. You'll simulate one.

Steps

1. Gather a pneumatic cylinder model, manual pump, valves, and limit switches.
2. Assemble the pneumatic system.
3. Program limit switches to control cylinder movement.
4. Test pressing action.

Questions

1. Why are pneumatics used instead of motors for some tasks?
2. What safety measures are needed in pneumatic systems?

You should undertake this activity 9.10 after the three you chose from 9.1-9.9.

Activity 9.10 Industrial Automation Site Visit & Guest Engineer Session

Seeing real systems in action makes learning come alive.

Steps

1. Arrange a visit to a factory or automation lab with PLC-based systems.
2. Observe motors, sensors, relays, contactors, and fluid power systems.
3. Take notes on diagrams, wiring, and safety procedures.
4. After the visit, meet with an automation engineer to discuss observations.

5. In groups, create a small model inspired by the visit.

Questions

1. What surprised you most during the visit?
2. How are PLCs used to control these systems?
3. How could what you saw be applied to solve problems in your community?

PROGRAMMING PLCS AND USING THEM IN COMBINATION WITH OTHER COMPONENTS TO IMPLEMENT SIMPLE INDUSTRIAL AUTOMATION SYSTEMS BASED ON DESIGN CRITERIA

A Programmable Logic Controller (PLC) is a special type of computer used in factories and machines to collect signals from sensors, make decisions based on programmed instructions, and control devices like motors, lights, and alarms.

Basic Components

- a. CPU (processes logic)
- b. Input module (e.g., sensors, switches)
- c. Output module (e.g., motors, relays)
- d. Power supply
- e. Programming interface (USB or Ethernet)

Basics of PLC Programming

- a. Programming Language: Ladder Logic (resembles relay logic diagrams)
- b. Common Instructions
 - i. Contacts: Normally Open (NO), Normally Closed (NC)
 - ii. Coils: Output actuators
 - iii. Timers and Counters: TON, TOF, CTU
 - iv. Set/Reset: Latching/unlatching
 - v. Compare: Greater than, less than
 - vi. Branching & Sequencing

Interfacing PLCs with Components

Input Components	Output Components
Push buttons	Motors (AC/DC)
Limit switches	Indicator lamps
Proximity sensors	Solenoids
IR sensors	Relays and contactors
Temperature/humidity sensors	Buzzers

Design and Implementation Process

Step-by-Step Approach

- i. Understand the Design Criteria
 - What process needs automation?
 - What are the conditions to control?
- ii. Identify Inputs/Outputs
 - Inputs (e.g., start button, sensor trigger)
 - Outputs (e.g., motor on, lamp on)
- iii. Design the Control Logic
 - Draw a process flow diagram
 - Write logic using ladder diagrams
- iv. Implement the System
 - Program the PLC
 - Connect components
 - Test and debug
- v. Evaluate and Refine
 - Check for logic errors or sensor malfunctions
 - Optimise response time and safety

Example 1: PLC-Controlled Conveyor Belt System

- 1. **Problem:** Design an automated conveyor system using Arduino. The conveyor belt should start moving when a Start button is pressed and stop automatically when an object is detected at the end of the belt.
- 2. **Components**
 - Arduino Uno
 - Breadboard and jumper wires

- Start push button
- Stop push button (optional for manual stop)
- Inductive proximity sensor (or IR sensor for object detection)
- Relay module
- DC motor (to simulate the conveyor belt)
- 12V power supply (for the motor)

3. Logic Summary

- a. When the Start button is pressed, the Arduino turns ON the motor using a relay module.
- b. When the sensor detects an object at the end of the conveyor, the Arduino turns OFF the motor.
- c. You can also add a manual Stop button if needed.

4. Ladder Logic Overview

- a. Pressing the Start button activates a latch in code (stores a value in memory) to turn the motor ON.
- b. The sensor at the end detects the object and resets the latch, turning the motor OFF.

5. Code

```
const int startButton = 2;
const int sensorPin = 3;
const int relayPin = 8;
bool motorRunning = false;
void setup() {
  pinMode(startButton, INPUT_PULLUP);
  pinMode(sensorPin, INPUT);
  pinMode(relayPin, OUTPUT);
  digitalWrite(relayPin, LOW); // Motor OFF initially
}
void loop() {
  if (digitalRead(startButton) == LOW && !motorRunning) {
    motorRunning = true;
    digitalWrite(relayPin, HIGH); // Turn motor ON
  }
  if (digitalRead(sensorPin) == HIGH && motorRunning) {
    motorRunning = false;
    digitalWrite(relayPin, LOW); // Turn motor OFF
  }
}
```

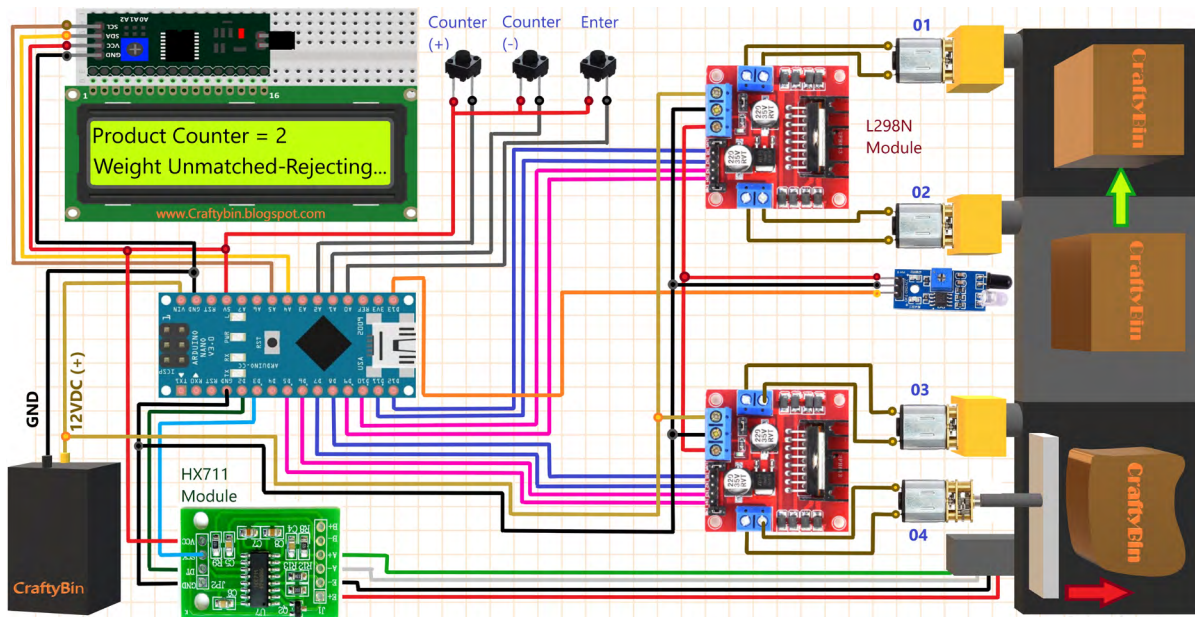


Figure 9.3: Picture of PLC Controlled Conveyor Belt System

Example 2: Automated Water Tank Filling System

1. **Problem:** Design an automatic water tank filling system using Arduino. The system should turn ON the water pump when the tank is low and turn it OFF when the tank is full using two float sensors.
2. **Components**
 - a. Arduino Uno
 - b. Two float switches (Low level and High level)
 - c. Relay module
 - d. Submersible or external water pump
 - e. Jumper wires and breadboard
 - f. 12V or 5V power supply (depending on pump rating)
3. **Control Logic**
 - a. If the Low sensor is not activated (water is low): Turn ON the pump.
 - b. If the High sensor is activated (tank is full): Turn OFF the pump.
 - c. This creates a simple automatic water level controller using float switches.
4. **Code**

```
const int lowSensor = 2; // Low-level float switch
const int highSensor = 3; // High-level float switch
const int pumpRelay = 8; // Relay controlling the pump

void setup() {
  pinMode(lowSensor, INPUT_PULLUP); // Use INPUT_PULLUP for float switches
  pinMode(highSensor, INPUT_PULLUP);
  pinMode(pumpRelay, OUTPUT);
  digitalWrite(pumpRelay, LOW); // Pump OFF initially
}

void loop() {
  bool lowLevel = digitalRead(lowSensor); // LOW when activated
  bool highLevel = digitalRead(highSensor); // LOW when activated
```

```

if (lowLevel == HIGH && highLevel == HIGH) { // Water is low and not full — turn
    pump ON digitalWrite(pumpRelay, HIGH); }
if (highLevel == LOW) { // Water has reached high level — turn pump OFF
    digitalWrite(pumpRelay, LOW); } }

```

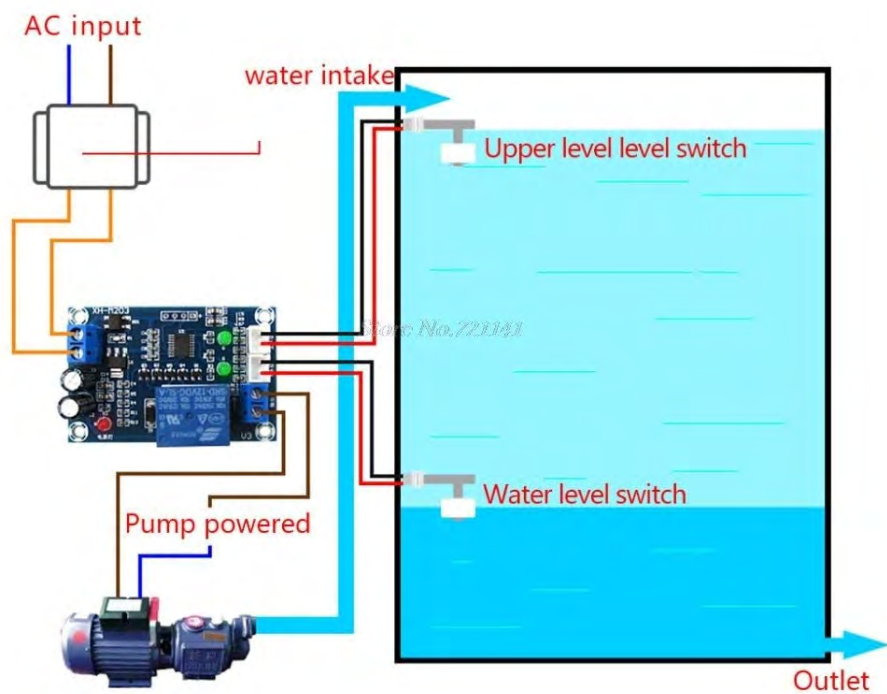


Figure 9.5: A picture of the Automated Water Tank Filling System

Activities – choose TWO of the following activities 9.11 – 9.19 AND 9.10 (three in total - the rest are optional)

Activity 9.11 Conveyor Belt Bottle Sorting

Steps

1. Form groups of four and imagine you are in a beverage factory.
2. You will visit an industrial automation lab or a site with a PLC controlling a conveyor belt.
3. Observe how proximity sensors detect the presence of bottles and send signals to the PLC.
4. Watch how the PLC controls motors to move bottles and actuators to push them into bins based on size or shape.
5. Sketch the engineering diagram from the control panel display and label each component.

Questions

1. What role did the proximity sensor play in this system?
2. How did the PLC decide which bin to send each bottle to?

Activity 9.12 Automatic Gate Control

Steps

1. Visit a factory entrance or lab setup with an automatic gate.
2. Observe how an IR motion sensor or RFID reader detects incoming vehicles.
3. The PLC receives this input and signals a motor-driven gate arm to open.
4. Use the PLC software to view the ladder logic controlling the system.
5. Identify the relays and contactors in the control panel and note their functions.

Questions

1. Why is it important to have a sensor before the gate opens?
2. What would happen if the contactor failed?

Activity 9.13 Packaging Machine Speed Control

Steps

1. In the lab, set up a small PLC-controlled motor connected to a conveyor.
2. Install a rotary encoder sensor to measure speed.
3. Program the PLC to increase or decrease speed based on the number of products passing per minute.
4. Test the system and record the results.

Questions

1. How does the PLC use encoder signals to control motor speed?
2. What adjustments would you make to improve accuracy?

Activity 9.14 Fluid Pump Control in a Factory

Steps

1. Visit an industrial site with a fluid power system (e.g., water pumping or hydraulic press).
2. Identify the pressure sensors feeding data to the PLC.
3. Observe how the PLC opens or closes valves using solenoid actuators.
4. Draw a flow diagram showing how the sensor data moves through the PLC to the actuator.

Questions

1. What happens if the pressure sensor sends wrong readings?
2. How can the PLC be programmed to prevent system damage?

Activity 9.15 Smart Lighting System

Steps

1. Set up a light sensor connected to a PLC in the lab.
2. Program the PLC so that when light levels drop below a certain value, relays switch on LED lights.
3. Simulate night and day using a torchlight or covering the sensor.
4. Test and document how the system responds.

Questions

1. Why is a relay needed between the PLC and the lights?
2. How could this system save energy in a factory?

Activity 9.16 Robotic Arm Sorting

Steps

1. Watch a robotic arm controlled by a PLC in the automation lab.
2. See how proximity sensors and colour sensors send inputs to the PLC.
3. Observe how the PLC signals the robotic arm to sort objects into trays.
4. Take notes on how the arm's movement sequence is programmed.

Questions

1. What happens if the sensor detects the wrong colour?
2. How does the PLC ensure precise timing for the robotic arm?

Activity 9.17 Temperature-Controlled Cooling System

Steps

1. In a lab setup, connect a temperature sensor to a PLC.
2. Program the PLC to turn on a cooling fan motor if the temperature exceeds a set point.
3. Simulate a rise in temperature using a hair dryer on the sensor.
4. Record the time taken for the fan to start after the threshold is reached.

Questions

1. Why is it important to set an accurate temperature threshold?
2. How would you make this system more energy efficient?

Activity 9.18 Automatic Bottle Filling System

Steps

1. Visit a packaging line or lab model where level sensors detect when a bottle is in place.
2. Observe how the PLC opens a valve actuator to fill the bottle.
3. Watch how the PLC stops the filling when the bottle reaches a set level.
4. Draw the input-output diagram for the system.

Questions

1. Why does the PLC need both a start and a stop signal for this process?
2. How could you prevent overfilling?

Activity 9.19 Emergency Stop Circuit

Steps

1. In the automation lab, locate an emergency stop button in a PLC-controlled system.
2. Press the button and note how it stops motors, pumps, and actuators instantly.
3. Study the wiring diagram to see how the button is connected to the PLC and contactors.
4. Discuss why emergency stops are critical in automation.

Questions

1. What would happen if the emergency stop button fails?
2. Should the PLC or hardware components handle safety shutdowns? Why?

You should undertake this activity 9.20 after the three you chose from 9.11-9.19.

Activity 9.20 Inviting an Automation Engineer

Steps

1. Organise a session where a factory automation engineer visits your class.
2. Prepare questions about motors, sensors, PLCs, contactors, relays, and fluid power systems before the session.
3. Take notes on how PLC programming is applied in real-world projects.
4. Compare the engineer's explanations with your site/lab observations.

Questions

1. Which part of the PLC-controlled system did you find most challenging to understand?
2. How does hearing from an industry expert make the learning more relevant?

DESIGNING EMBEDDED SYSTEMS TO INTERFACE WITH SENSORS AND ACTUATORS GIVEN DESIGN OBJECTIVES

An embedded system is a combination of hardware and software designed to perform a specific, dedicated function within a larger system.

- 1. Controlled by a microcontroller (e.g., Arduino, STM32, Raspberry Pi Pico)
- 2. Interacts with the physical world using:
 - a. Sensors (inputs) to detect conditions
 - b. Actuators (outputs) to perform actions

Design Process Overview

Step	Description
Define the Problem	Understand the need or task (e.g., automate lighting based on room occupancy).
Select Components	Choose appropriate sensors, actuators, and a microcontroller.
Design the Circuit	Create schematics to connect all components correctly.
Write the Code	Program the microcontroller to process inputs and control outputs.
Build & Test	Assemble the system and verify it works as intended.
Refine	Troubleshoot and improve performance.

Key Components in Embedded Design

- a. Microcontrollers (Processing Unit)
Examples: Arduino Uno, ESP32, Raspberry Pi Pico
Role: Runs software to read inputs and control outputs
- a. Sensors (Inputs)
Sensors gather data from the environment

Sensor	Measures	Signal Type
LDR	Light	Analog
DHT11/DHT22	Temp & Humidity	Digital
Ultrasonic Sensor	Distance	Digital

IR Sensor	Motion or obstacle	Digital
Soil Moisture	Wetness	Analog

b. Actuators (Outputs)

Devices that perform actions based on microcontroller commands.

Actuator	Function
Servo Motor	Precise angle control
DC Motor	Rotational movement
Relay	Switch AC/DC loads
LED	Light signal
Buzzer	Audio alarm

Interfacing Sensors and Actuators

1. Hardware Interface
 - a. Sensors → Microcontroller Input Pins
 - b. Actuators → Microcontroller Output Pins (may need transistors or relays for high-current devices)
2. Power supply must match voltage/current requirements
3. Programming Logic
4. Using Arduino-style pseudocode:

Code

```
int sensorValue = analogRead(A0);
if (sensorValue < threshold) {digitalWrite(LED, HIGH); // turn ON actuator} else
    {digitalWrite(LED,LOW); // turn OFF actuator}
```

Programming Considerations

1. Use libraries like Servo.h, DHT.h, NewPing.h when needed
2. Handle sensor noise with averaging or hysteresis
3. Use timers to delay actions (e.g., millis() instead of delay() for non-blocking code)
4. Modularise code into functions

Design Considerations

Factor	Description
Cost	Minimise unnecessary components
Power Efficiency	Use sleep modes or low-power devices
User Interface	Add LEDs, LCDs, or buzzers for feedback
Environment	Consider waterproofing or casing for outdoor use
Scalability	Allow for easy updates or expansion

Assessment Ideas

Task	Criteria
Mini project	Working with an embedded system with clear function
Circuit diagram	Accurate wiring with correct pin usage
Code quality	Clean logic, comments, functional outcome
Troubleshooting	Ability to identify and fix issues
Design report	Description of objective, design choices, and testing results

Tools for Simulation and Prototyping

Tool	Use
Tinkercad Circuits	Online simulation of Arduino circuits
Fritzing	Design circuit diagrams
Proteus	Advanced simulation with real-time feedback
Arduino IDE	Programming environment

Example Projects

Example 1: Automatic Room Light System

Design Objective: The light turns ON when someone enters the room and OFF after a delay.

Components

- PIR Motion Sensor
- Relay Module

- Light Bulb or LED
- Arduino Uno

Logic

1. Sensor detects motion → Arduino activates relay → light turns ON
2. After no motion for a set time → light turns OFF

Automatic Room Light Controller with Bidirectional Visitor Counter

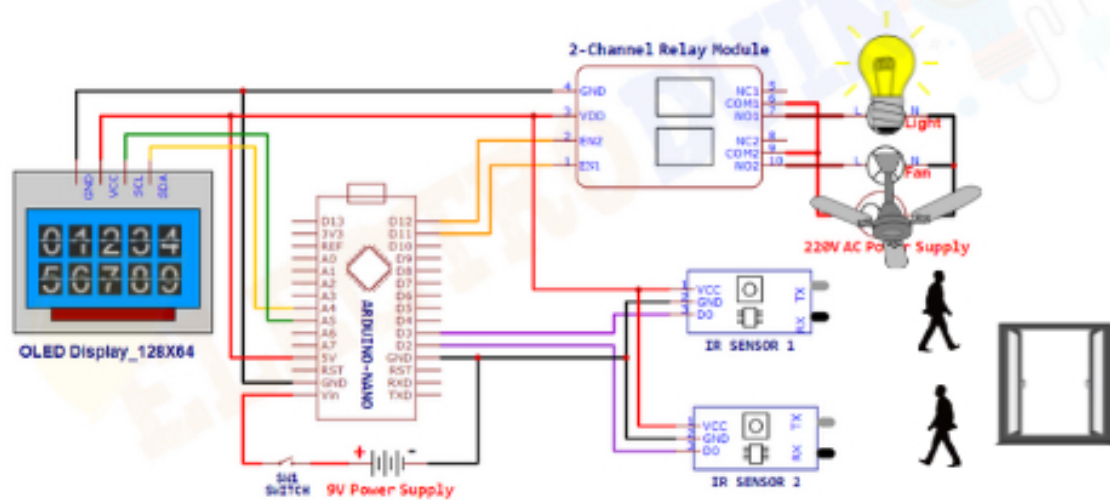


Figure 9.6: A picture of an automatic room light system

Example 2: Smart Plant Watering System

Design Objective: Water the plant only when the soil is dry.

Components

1. Soil Moisture Sensor
2. Relay Module
3. Water Pump
4. Arduino Uno

Logic

- i. If soil moisture < threshold → activate relay → pump ON
- ii. Else → pump OFF



Figure 9.7: A picture of a Smart Plant Watering System

Example 3: Fire or Gas Leak Alarm System

Design Objective: Trigger a buzzer and alert when fire or gas is detected.

Components

- Flame or MQ2 Gas Sensor
- Buzzer
- Arduino Uno

Logic

If sensor signal exceeds safe level → buzzer ON

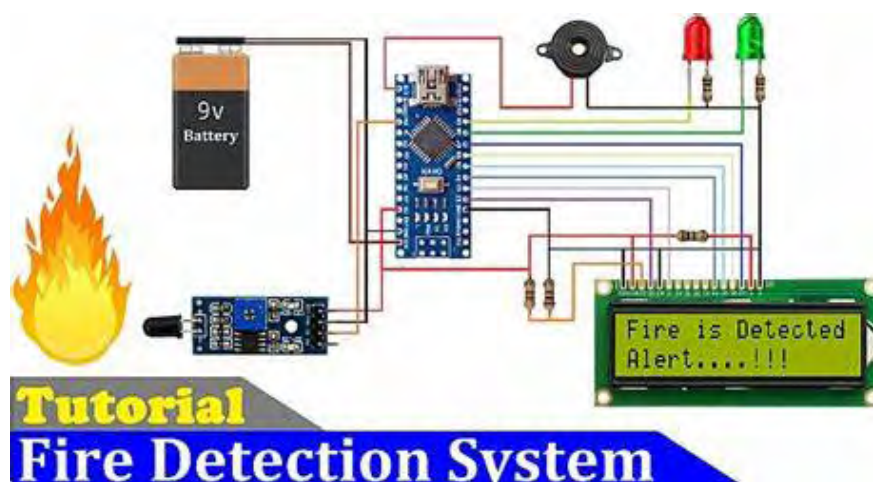


Figure 9.8: A picture of a Fire Alarm System using Arduino

Example 4: Smart Dustbin

Design Objective: Open the lid when a person approaches.

Components:

- Ultrasonic Sensor
- Servo Motor
- Arduino Uno

Logic

1. If distance < 20cm → rotate servo to open lid
2. After delay → close lid

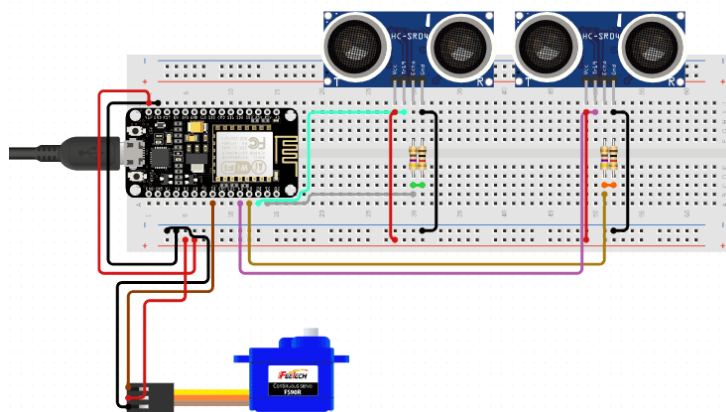


Figure 9.9: A picture of Smart Dustbin

Activities – choose TWO of the following activities 9.21 – 9.30 AND 9.31 (three in total - the rest are optional)

Activity 9.21 Automatic Plant Watering System

Introduction: You are responsible for keeping your classroom plants healthy. Instead of watering them manually, you'll design a system that senses soil moisture and turns on a small water pump automatically.

Steps

1. Each group should collect an Arduino board, soil moisture sensor, mini water pump, jumper wires, breadboard, and USB cable.
2. Insert the soil moisture sensor into the plant pot.
3. Connect the sensor to the Arduino following the pin diagram.
4. Connect the water pump to a digital pin through a relay.
5. Write a simple code to turn the pump ON when the soil is dry and OFF when wet.
6. Upload the code and test by drying and wetting the soil.

Question: How does the soil moisture sensor's reading affect the pump's operation?

Activity 9.22 Proximity-Activated Door Light

Introduction: You want your room light to turn on when you approach and turn off when you leave.

Steps

1. Gather Arduino board, ultrasonic distance sensor, LED, resistors, jumper wires, and breadboard.
2. Mount the ultrasonic sensor on the breadboard and connect it to the Arduino.
3. Connect the LED to a digital output pin through a resistor.
4. Write code to detect when a person is within 1 metre and turn the LED on.
5. Test by moving towards and away from the sensor.

Question: What would happen if you increased the detection range in the code?

Activity 9.23 Motion-Activated Alarm

Introduction: You need a system to alert you when someone enters your study space.

Steps

1. Use Arduino, PIR motion sensor, buzzer, jumper wires, and breadboard.
2. Connect the PIR sensor to a digital input pin.
3. Connect the buzzer to a digital output pin.
4. Program the Arduino to sound the buzzer when motion is detected.
5. Test by walking past the sensor.

Question: How can you make the alarm sound only at night?

Activity 9.24 Smart Room Temperature Fan Control

Introduction: Design a fan that turns on automatically when it gets too warm.

Steps

1. Gather Arduino, temperature sensor (LM35/DHT11), DC motor, jumper wires, and breadboard.
2. Connect the temperature sensor to the Arduino.
3. Connect the DC motor through a transistor or motor driver.
4. Program the system to turn the fan ON when the temperature exceeds 28°C.
5. Test using a warm object near the sensor.

Question: What changes would you make if you wanted the fan to work for both heating and cooling?

Activity 9.25 Sound-Activated Desk Lamp

Introduction: You want to clap your hands to turn your desk lamp on or off.

Steps

1. Use Arduino, sound sensor module, LED, jumper wires, and breadboard.
2. Connect the sound sensor to a digital input pin.
3. Connect the LED to a digital output pin.
4. Write a program to toggle the LED when a loud clap is detected.
5. Test by clapping near the sensor.

Question: How can you reduce false triggers from background noise?

Activity 9.26 Light-Sensitive Night Lamp

Introduction: Make a lamp that turns on only when it's dark.

Steps

1. Gather Arduino, LDR (light-dependent resistor), LED, resistor, jumper wires, and breadboard.
2. Connect the LDR to an analogue input pin.
3. Connect the LED to a digital output pin.
4. Program the system to turn the LED ON when the light level drops below a certain threshold.
5. Test by covering the LDR.

Question: What happens if you reverse the light level threshold?

Activity 9.27 Distance-Based Obstacle Alert for Cyclists

Introduction: You want a safety alert when an object gets too close to the back of your bicycle.

Steps

1. Use Arduino, ultrasonic sensor, buzzer, jumper wires, and breadboard.
2. Mount the ultrasonic sensor to detect objects behind you.
3. Connect the buzzer to a digital output pin.
4. Write a program to sound the buzzer when an object is within 50 cm.
5. Simulate with a friend walking towards the sensor.

Question: How could this be adapted for use in cars?

Activity 9.28 Pressure-Activated Welcome Mat

Introduction: A welcome mat that plays a tune when someone steps on it.

Steps

1. Gather Arduino, pressure sensor, piezo buzzer, jumper wires, and breadboard.
2. Connect the pressure sensor to an analogue input pin.
3. Connect the buzzer to a digital output pin.
4. Program the buzzer to play a short melody when pressure is detected.
5. Test by stepping on the mat.

Question: How could you use this idea for security purposes?

Activity 9.29 Smart Window Blinds

Introduction: Window blinds that open when it's bright outside and close when it's dark.

Steps

1. Gather Arduino, LDR, servo motor, jumper wires, and breadboard.
2. Connect the LDR to an analogue pin.
3. Connect the servo motor to a PWM digital pin.
4. Write code to rotate the blinds open or closed based on light levels.
5. Test by shining a flashlight on the LDR.

Question: What would you need to add if you wanted this to be remote-controlled?

Activity 9.30 Accident Impact Detection for Bicycles

Introduction: A device that detects sudden movement (impact) and triggers a buzzer for an emergency alert.

Steps

1. Gather Arduino, accelerometer module, buzzer, jumper wires, and breadboard.
2. Connect the accelerometer to Arduino via I2C pins.
3. Connect the buzzer to a digital output pin.
4. Write code to sound the buzzer when a sudden high acceleration is detected.
5. Simulate an impact by shaking the accelerometer.

Question: How could this system send a message to emergency contacts?

This final activity (9.31) wraps all the learning from Y1-Y3 together. This will help you revise all you have learnt under this section.

Activity 9.31 Home Automation Prototype Using Arduino

Objective: To design an embedded system that controls household devices like lights and fans based on sensor input.

Materials Needed

- Arduino Uno
- PIR sensor or IR sensor
- LDR
- Relay module
- LEDs
- LCD display
- Resistors, capacitors, transistors
- Breadboard, jumper wires

Steps

1. You design a system where an LED (representing a light bulb) turns on automatically in a dark room when motion is detected.
2. A relay controls a fan based on temperature readings.
3. LCDs current room status.
4. You simulate or build a fixed electronic circuit for the same function and compare it with the Arduino solution.

Question: What are the limitations of using a fixed electronic circuit in this context compared to Arduino?

EXTENDED READING

- Lamb, F. (2013). Industrial Automation: Hands-On. United States: McGraw-Hill LLC.
- Manesis, S., Nikolakopoulos, G. (2020). Introduction to Industrial Automation. United Kingdom: Taylor & Francis Group.

REVIEW QUESTIONS

1. A small bottling plant needs an automated conveyor system to move bottles to a filling station. The system should start when a sensor detects a bottle, run the motor to move it to the filling station, and stop when the filling sensor is triggered. What combination of components would you select, and how would you connect them?
2. In a pneumatic press system, the press should only activate when two safety switches are pressed at the same time. What is the purpose of this requirement, and how can you design the control circuit?
3. A warehouse wants an automated door that opens when a forklift approaches and closes automatically after 15 seconds. Which components would you use, and how would they work together?
4. A sorting line needs to direct red boxes to one path and blue boxes to another using actuators. How can you design the detection and actuation system?
5. A farm irrigation system needs to activate a water pump when soil moisture is low and stop when it's sufficient. Which automation components would you use and why?
6. A car wash conveyor must move cars forward only after the washing stage is complete. What sensing method would you choose, and how would you integrate it?
7. A packaging machine uses a motor to feed plastic film and a pneumatic cutter to cut it after every 50 cm. How can you synchronise these operations?
8. In a fluid power lifting system, the lift must stop automatically if it reaches maximum height or if an emergency stop button is pressed. How would you design this safety feature?
9. A production line wants to count the number of products passing a point and stop the conveyor after 100 products. Which automation components are suitable?
10. You are tasked with designing a small assembly line that uses motors, sensors, and actuators to assemble toy cars. The first station attaches wheels, the second paints, and the third packages. How can you ensure each stage only starts when the previous stage is complete?
11. You are tasked to automate a conveyor belt system that sorts items into two bins based on their size detected by a sensor. The motor should stop if no item is detected for 10 seconds. Describe how you would program the PLC and connect the components.
12. An automated car wash system must spray water for 5 seconds, then soap for 7 seconds, then rinse for 10 seconds. Which PLC instructions would you use and in what sequence?
13. A factory needs an automatic gate to open when a proximity sensor detects a vehicle and close 3 seconds after the vehicle passes. How would you integrate the sensor and gate motor into your PLC program?
14. You are designing a PLC-controlled mixing machine. The mixer runs for 30 seconds, then stops for 15 seconds before restarting. How will you create this repeating cycle in your program?

15. An industrial packaging machine must print labels only when the packaging compartment is closed and the conveyor is running. Which logic condition should you use?
16. You need to control a pump that fills a tank. The pump starts when the low-level sensor is activated and stops when the high-level sensor is reached. Which PLC logic type is suitable and why?
17. A warehouse wants a light to turn ON when a motion sensor detects movement but turn OFF automatically after 1 minute of no activity. Which PLC instruction can help achieve this?
18. In a bottling plant, you need to count bottles passing through a sensor and stop the conveyor after 50 bottles. How will you program this in the PLC?
19. A production line requires that a fan turns ON when temperature exceeds 40°C and turns OFF when it drops below 35°C. How can this be implemented in a PLC program?
20. An automatic lift system should move up when the “Up” button is pressed, but only if the top limit switch is not activated. Similarly, it should move down when the “Down” button is pressed, but only if the bottom limit switch is not activated. What PLC logic conditions will ensure safe operation?
21. You are designing a smart irrigation system that waters plants automatically when soil moisture drops below a set threshold. Which sensor and actuator would you choose, and how would you control them using an embedded system?
22. A parking lot system must detect when a car enters and displays the available spaces on a digital screen. Which components are needed, and how will the embedded system interact with them?
23. You are tasked to build a temperature-controlled fan for a greenhouse that turns ON above 28°C and OFF below 25°C. Which embedded logic should you implement?
24. A factory conveyor must stop if an object gets jammed. The system should also trigger a red warning light. How will you design this interface?
25. You need to create an automatic door system that opens when someone approaches and closes after 5 seconds. Which components will you use, and how will you control the timing?
26. You are designing a safety system for a gas storage area. An alarm must sound when gas leakage is detected. Which sensor and actuator are suitable, and how would the microcontroller respond?
27. A smart waste bin should open its lid when a hand is waved over it and close after 3 seconds. How will you implement the system?
28. You must design a street lighting system that turns lights ON at night and OFF in the morning automatically. Which sensor will you use, and how will you control the actuator?
29. You need a security system that captures an image when motion is detected. What is the basic hardware design?
30. A production machine must dispense exactly 100 ml of liquid each cycle. How will you achieve precise measurement and actuation?

REFERENCES

1. Bogatin, E. (2021). *Bogatin's practical guide to prototype breadboard and PCB design*. Artech House.
2. Clarke, D. S., Burke, P. R. J., & Cooper, C. L. (2012). *Occupational health and safety*. Ashgate Publishing.
3. Dutta, S. K., Saxena, J., & Choudhury, B. K. (2022). *Energy efficiency and conservation in metal industries: With selected cases of investment-grade audit*. CRC Press.
4. *Engineering for sustainable development*. (2021). UNESCO.
5. F. Gardner, R. (2020). *Introduction to plant automation and controls*. CRC Press.
6. Foley, J. T., Cavique, M., & Suh, N. P. (2021). *Design engineering and science*. Springer International Publishing.
7. Harris, D. M., & Harris, S. L. (2013). *Digital design and computer architecture*. Elsevier Science.
8. Hossain, M. A., & Strezov, V. (2022). *Renewable energy systems from biomass: Efficiency, innovation and sustainability*. CRC Press.
9. Kamran, M., & Fazal, M. R. (2021). *Renewable energy conversion systems*. Elsevier Science.
10. Kenney, W. F. (2012). *Energy conservation in the process industries*. Academic Press.
11. Kumar, A., Prakash, O., Chauhan, P. S., & Gautam, S. (2020). *Energy management: Conservation and audits*. CRC Press.
12. Liu, K. (2020). *Protection of health and safety at the workplace: A comparative legal study of the European Union and China*. Springer Nature.
13. May, V. V. (2015). *3-D engineering: Design and build your own prototypes*. Nomad Press.
14. Mehta, B. R., & Reddy, Y. J. (n.d.). *Industrial process automation systems: Design and implementation*. Butterworth-Heinemann.
15. Mitzner, K. (2009). *Complete PCB design using OrCAD Capture and PCB editor*. Newnes.
16. Mitzner, K. (2011). *Complete PCB design using OrCAD Capture and Layout*. Newnes.
17. Nagasekhar Reddy, P., Raja, G. V., Aravindhana, K., & Kumar, C. P. (2025). *Fundamentals of renewable energy*. RK Publication.
18. Niklasson, L. (2020). *Improving the sustainable development goals: Strategies and the governance challenge*. Taylor & Francis.
19. Pahl, G., & Beitz, W. (2013). *Engineering design: A systematic approach*. Springer.
20. Pathak, P., & Srivastava, R. R. (2021). *Alternative energy resources: The way to a sustainable modern society*. Springer International Publishing.
21. Pilavachi, P. A. (2012). *Energy efficiency in process technology*. Springer Netherlands.
22. *Professional ethics*. (2024). RK Publication.
23. Ramamoorthy, M., & Chandra Sekhar, O. (2017). *Electrical machines*. PHI Learning.
24. Raval, D. B. (2014). *A textbook of electrical machines*. Vikas Publishing House.
25. Robinson, S. (2007). *Engineering, business and professional ethics*. Taylor & Francis.

26. Rogdakis, E. D. (2018). *Renewable energy engineering: Solar, wind, biomass, hydrogen and geothermal energy systems*. Amazon Digital Services (KDP).
27. Sahdev, S. K. (2017). *Electrical machines*. Cambridge University Press.
28. Sharma, K. (2016). *Overview of industrial process automation*. Elsevier Science.
29. *Sustainable development for engineers: A handbook and resource guide*. (2017). Taylor & Francis.
30. *Sustainable development goals: Their impacts on forests and people*. (2019). Cambridge University Press.
31. Wendel, W. B. (2020). *Professional ethics and personal integrity*. Cambridge Scholars Publishing.
32. Westcott, J. R., Gupta, A., & Arora, S. (2023). *Industrial automation and robotics*. Mercury Learning and Information.

GLOSSARY

- **Actuator:** It is a device that acts in response to a signal from a controller (like an Arduino, PLC, or other embedded system).
- **Analyse failures:** It means to carefully look at what went wrong with your prototype and understand why it didn't work as expected.
- **Backup system:** They are designed to take over or support the primary system in case it fails or becomes unavailable.
- **Basic components:** They are the essential parts that make up a system or machine. They are the building blocks that work together to help the system function properly.
- **Bioenergy system:** This is a system that converts biomass (organic material from plants, animals, and waste) into usable energy such as heat, electricity, or biofuels.
- **Breadboard:** It is a reusable device used to build and test electronic circuits without soldering, making it ideal for prototyping and experimentation.
- **CAD:** It is a computer program that helps you draw and plan designs, such as electronic circuits or PCB layouts, so you can build them correctly.
- **CAM:** It is when computers and machines work together to build a real product—like a PCB—based on a design made on a computer (CAD).
- **Conscious:** Means being awake, aware of your surroundings, and able to respond to people, sounds, and other stimuli. A conscious person can think, speak, and move intentionally.
- **Conduct:** It refers to a person's behaviour, actions, and attitude, especially in a professional or organisational setting. It shows how someone behaves towards others and how they carry out their duties.
- **Conveyor:** It is a mechanical system that moves materials from one place to another, usually in factories or warehouses. It helps in speeding up production and reducing manual labour.
- **CPR (Cardiopulmonary Resuscitation):** It is an emergency life-saving procedure performed when the heart stops beating. It combines chest compressions and rescue breaths to help maintain blood flow and oxygen supply to the brain and vital organs until professional medical help arrives.
- **Design:** This means planning and creating something with a specific purpose or function in mind. It includes thinking about how something will work, look, and be built.
- **Designing:** Planning and creating solutions using creativity and technical skills.
- **Electronic circuit:** It is a group of connected electronic components (such as batteries, wires, resistors, and LEDs) that work together to perform a function when electricity flows through them.
- **Embedded system:** It is a special-purpose computer that is built into a larger machine or device to perform specific tasks.

- **Energy conservation:** It is the practice of reducing energy use through behavioural changes, efficient practices, or the elimination of unnecessary energy consumption.
- **Energy efficiency:** It is the ability to use less energy to perform the same task or produce the same result. It involves using technology and practices that reduce energy consumption while maintaining performance, comfort, or output.
- **Energy Management System (EMS):** It is a structured framework of tools, processes, and practices used to monitor, control, and optimise the production, distribution, and consumption of energy in a facility or organisation. Its main goal is to improve energy efficiency, reduce costs, and minimise environmental impact while ensuring reliable energy use.
- **Environmental degradation:** Damage to nature caused by human activities like pollution or deforestation.
- **Fracture:** It is a medical term that refers to a break or crack in a bone. It can range from a small hairline crack to a complete break and may be caused by accidents, falls, or strong impacts.
- **Function:** It is the job or role that something does.
- **Housekeeping:** Refers to the practice of keeping work areas clean, organised, and free of hazards. It includes activities like regular cleaning, proper storage of tools and materials, disposal of waste, and maintaining clear walkways to ensure a safe, efficient, and productive environment.
- **Industrial automation systems:** They are technology-driven setups that utilise components such as motors, sensors, actuators, relays, switches, programmable logic controllers (PLCs), and embedded controllers to monitor, control, and execute industrial processes such as manufacturing, sorting, packaging, and assembly. These systems operate with minimal human intervention, ensuring efficiency, accuracy, and consistency.
- **Innovative solution:** A new or improved creative way to solve a problem.
- **Install:** This means to set up and fix something in place so it can be used.
- **Lathe:** It is a machine tool that rotates a workpiece while a cutting tool shapes it. It is mainly used for cutting, sanding, drilling, or turning materials like metal or wood into the desired shape.
- **Maintain:** This means to keep something in good working condition, so it works properly for a long time.
- **Methodology:** It is the systematic approach used to plan, structure, and carry out a task, project, or research. It includes the methods, tools, and procedures chosen to achieve specific objectives, ensuring consistency, reliability, and clarity throughout the process.
- **Operate:** This means to make something work or use it to do its job.
- **PCB (Printed Circuit Board):** It is a flat board that holds and connects electronic parts. It replaces messy wires with neat copper lines (called traces) to make the circuit work properly.
- **Programmable Logic Controller (PLC):** It is a digital industrial computer that automates and controls electromechanical processes by receiving inputs from

sensors or user commands, processing the data using programmed logic, and sending outputs to control devices like motors, relays, or actuators.

- **Professional bodies:** They are organisations made up of people in the same profession. They are responsible for setting and maintaining standards, promoting ethics, offering training, and protecting both the public and the reputation of the profession.
- **Professional code of ethics:** It is a set of rules or principles that guide how professionals should behave in the workplace and in society. It outlines what is right, fair, and responsible within a profession.
- **Prototyping:** It is the process of creating an early sample, model, or version of a product or system to test and evaluate its design, features, and functionality. It allows designers and engineers to explore ideas, identify problems, gather user feedback, and make improvements before building the final version.
- **Sensor:** It is a device that detects or measures a physical property in the environment and converts it into a signal that a system (like an embedded system) can understand.
- **Societal development:** Improvement in how people live and interact in a community.
- **Solderless breadboard:** It is a plastic board with holes that lets you build and test electronic circuits quickly without permanently attaching the components.
- **Sustainable Development Goals (SDGs):** 17 UN goals to end poverty and protect the planet by 2030.
- **Systems Design:** It is the process of planning and creating a complete and functional system by defining its structure, components, interactions, and processes to meet specific objectives or solve a problem. It involves identifying user needs, setting system requirements, designing hardware and software components, and ensuring that all parts work together efficiently and effectively.
- **Testing a prototype:** It means trying out a model or early version of your idea (called a prototype) to see how well it works, what problems it has, and how it can be improved.
- **Unconscious:** Means being unaware of your surroundings and unable to respond to people, sounds, or physical touch. An unconscious person cannot think, speak, or move intentionally and may need immediate medical attention.
- **Unplanned shutdowns:** They are unexpected interruptions in the operation of equipment, machines, or systems due to faults, failures, or emergencies.
- **Validate a prototype:** It means to test and confirm that the prototype meets the intended design goals, functions correctly under expected conditions, and solves the problem it was created to address. Validation ensures that the prototype performs as required, is safe to use, and meets user needs before full production or implementation.
- **Violation of code of ethics:** It happens when a person behaves in a way that goes against the accepted rules, values, or professional standards of conduct. This means they have broken the ethical principles set by their profession or organisation.

- **Wind energy system:** This is a setup that captures the kinetic energy of the wind and converts it into usable electrical power using wind turbines.