



CHEM-E CAR

TRAINING

MODULE



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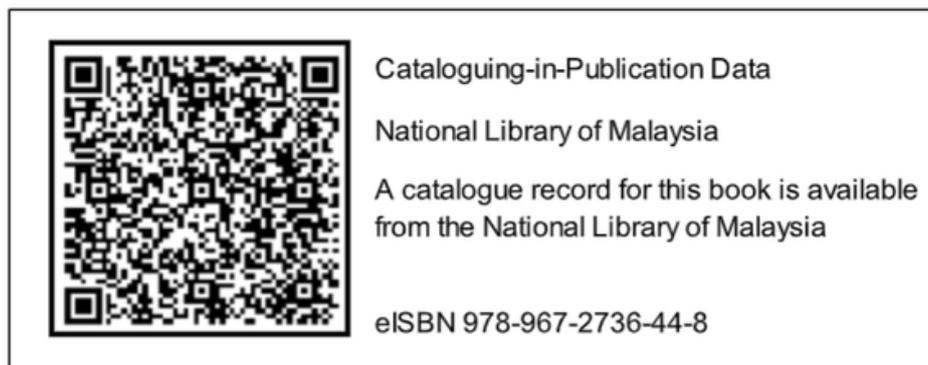
CHEM-E CAR

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MODULE

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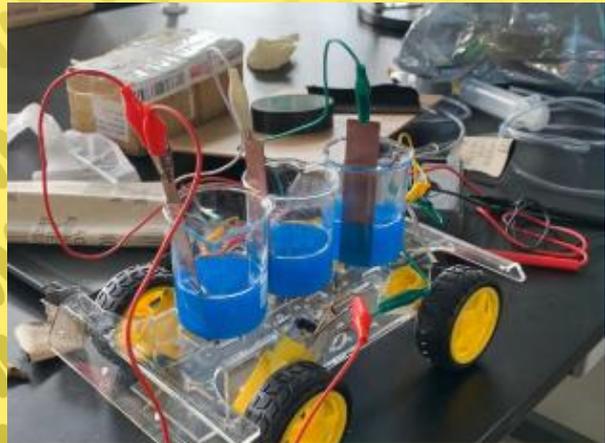
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PREFACE



Assoc. Prof. Dr. Siti Noorjannah Ibrahim
Project Leader

CHEM-E CAR SPARKING INNOVATION IN THE STUDENT ZONE 2026

Alhamdulillah, all praise is due to Allah for the successful development and publication of the Chem-E Car Module. This module is the result of collaborative efforts between Integrative Engineering Education and Ethics for Sustainability Research Group (INTEGRATES) and Bioprocess and Molecular Engineering Research Unit (BPMERU) of the Kulliyah of Engineering, International Islamic University Malaysia (IIUM), and the Chem-E Car Club of Politeknik Tun Syed Nasir. The collaboration reflects a shared commitment to engineering education through experiential learning, interdisciplinary collaboration in value-based education, and TVET.

We are really grateful for the opportunity to contribute in this meaningful project which was made possible through the generous support and funding of the UNESCO SKUM Grant, the Ministry of Higher Education Malaysia, and Research Management Centre (RMC) IIUM.

The Chem-E Car Module is designed as a hands-on learning resource to the application of chemical engineering principles; through the design and construction of a small chemically powered car. This module combines engineering design, scientific experimentation, teamwork, and ethical reflection to provide a meaningful and holistic learning experience.

Through this module, students will be able to explore how chemical reactions can be converted into mechanical energy that is used to move a car without relying on conventional fuels. The guided activities assist students to understand the key concepts such as reaction control, energy conversion, safety, and optimisation, while encouraging creativity and problem-solving through the iterative design.

PREFACE

In addition to technical learning, the uniqueness of Chem-E Car Module lies on the strong emphasis of ethics and sustainability based on Islamic worldview. Students are guided to reflect on issues of zero-carbon approaches, responsible use of materials and waste management, and to understand that engineering decisions movements have real impacts on people, environment and future generations.

Ethical reflection is woven throughout the module to reinforce the idea that engineering is not value-neutral, but a discipline that carries responsibility. By integrating hands-on engineering practice with ethical awareness, this module aspires to nurture future engineers who are environmentally conscious and guided by responsibility in their pursuit of innovation.

Overall, Chem-E Car Module aims to serve as both; a learning guide and a source of motivation for students and educators. Looking forward, it is our aspiration that this module will serve as a living resource that continues to evolve, adapt, and expand across institutions, educational levels, and communities.



HOW TO USE THE MODULE

Chem-E Car Module is designed to be flexible and adaptable, allowing it to be used in classrooms, workshops, competitions, and outreach programmes. It may be implemented as a complete learning package or parts selection, depending on the learning objectives, time available, and participants' levels.

This module is designed to suit:

1. Participants of Chem-E Car activities or competitions
2. Educators and facilitators of hands-on engineering activities
3. Anyone who is seeking to integrate sustainability and ethics into engineering education

The module is organised into three main components:

Part 1 : Engineering Ethics and Sustainability

The engineering ethical considerations based on Islamic worldview are embedded throughout the module. Students are guided to reflect on:

- sustainability and zero-carbon approaches
- responsibility the use of materials and waste management
- The broader impact of engineering decisions on society and the environment
- students understanding that engineering solutions must be both effective and responsible.

Part 2 : Design and Reflection Activities

In this part, reflection prompts, case studies, and design challenges are included to encourage critical thinking. Students are invited to:

- evaluate their design choices
- propose improvements with reduced environmental impact
- connect technical work with ethical responsibility

HOW TO USE THE MODULE

Part 3 : Technical Learning

This section guides students through the principles of Chem-E Car design, including:

- chemical reactions and energy conversion
- car construction and motion control
- data collection, analysis, and optimisation

Students are encouraged to complete experiments, record observations, and improve their designs through testing and reflection.

GUIDES FOR STUDENTS

1. Students are encouraged to:
 - a. read each section carefully before starting an activity
 - b. work collaboratively in teams during experiments and design tasks
 - c. record data, sketches, and reflections directly in the workbook
 - d. reflect honestly on both technical performance and ethical considerations.
2. Students should approach this module not only as a technical challenge, but also as an opportunity to develop responsible engineering habits.

GUIDES FOR EDUCATORS AND FACILITATORS

1. Educators may use this module:
 - as a step-by-step guide for Chem-E Car projects
 - as a supplementary resource for laboratory or project-based learning
 - as preparation material for Chem-E Car competitions
2. Facilitators are encouraged to:
 - adjust the depth of discussion according to student level
 - emphasise safety and proper handling of materials
 - encourage discussion on sustainability and ethical decision-making
 - use reflection questions to guide meaningful conversations

HOW TO USE THE MODULE

Suggested Implementation

1. The module may be implemented:
 - a. Frequently sessions (e.g. weekly project-based learning)
 - b. As an intensive workshop or bootcamp
 - c. As a preparatory guide for competitions
2. Educators may choose to complete all sections or select specific experiments and ethics discussions that best suit their objectives.

Learning Approach

This module promotes:

- Hands-on learning through experimentation
- Critical thinking through analysis and reflection
- Ethical awareness through sustainability and responsibility discussions
- Teamwork and communication through collaborative design

By engaging fully with the activities, students are guided to see engineering as a discipline that serves both innovation and the greater good.



EDITORIAL TEAM



الجامعة الإسلامية العالمية ماليزيا
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA
يونس بن سينا
Garden of Knowledge and Virtue



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RESEARCH TEAM

INTEGRATES & BPMERU

The STEM BOOST: Chem-E Car aligns closely with the vision and mission of INTEGRATES, which aspires to be a centre of integrative engineering education and research with values and professional ethics. INTEGRATES is actively involved in engineering education research, the design and development of STEM educational modules, and contributions to policy discourse related to engineering education and sustainability. In line with its mission, the Chem-E Car module provides a platform for educational engagement that integrates engineering knowledge, ethics, sustainability, and values, encouraging students to reflect on responsible innovation and the societal impact of technology.

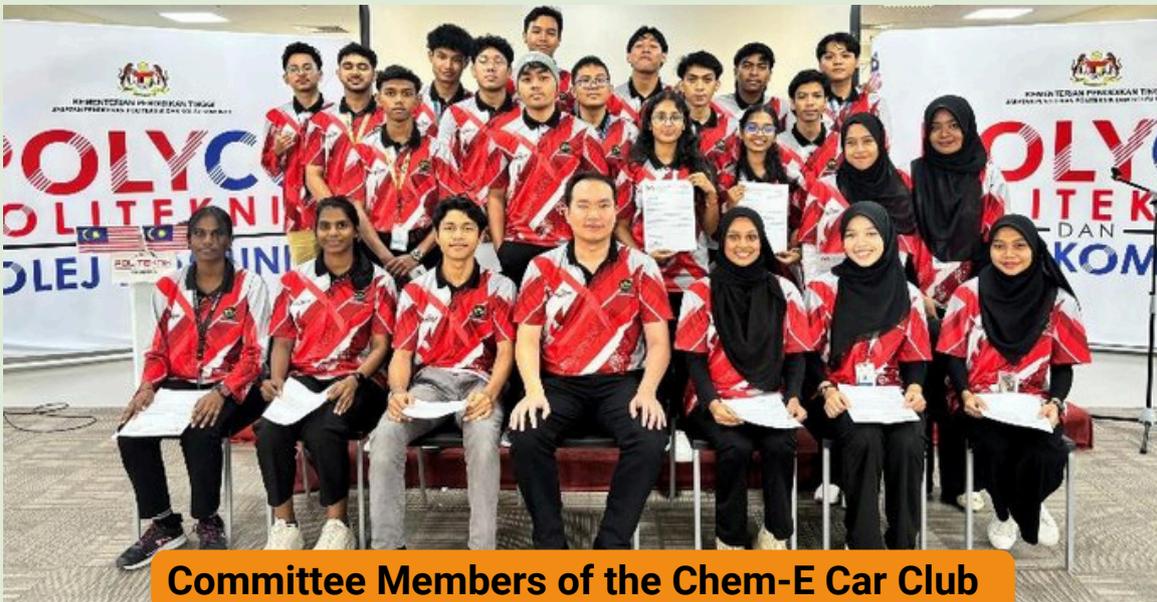
The programme is further supported by the Bioprocess & Molecular Engineering Research Unit (BPMERU), which focuses on research related to biological and chemical processes used in industries such as food, pharmaceuticals, bioenergy, and environmental engineering. BPMERU studies how enzymes, microorganisms, and plant or animal cells are used to produce useful products in a controlled and efficient manner.

In the Chem-E Car module, students apply similar ideas in a simplified and hands-on way. When students design and operate a Chem-E Car, they learn how a chemical reaction can be controlled to produce energy to move a vehicle. This reflects real chemical process engineering practices studied by BPMERU, where reactions must be carefully controlled to achieve the desired output safely, green and sustainably. Through this activity, students are introduced to basic concepts such as reaction control, energy efficiency, material selection, and environmental responsibility, helping them understand how chemistry is applied in real-world engineering and industrial processes.

CHEM-E CAR CLUB

Chem-E Car Club at Politeknik Tun Syed Nasir Syed Ismail (PTSN)

The Chem-E Car Club at Politeknik Tun Syed Nasir Syed Ismail (PTSN) is established to foster students' interest in chemical engineering, develop an understanding of sustainability concepts, and nurture creativity in designing chemically powered car. The club also exposes students to the practical applications of electrochemical cell and thermoelectric principles through the building of a small-scale car powered by chemical reactions.



Chem-E Car activities at PTSN began in 2023 as an initial step to introduce students to engineering and sustainable energy concepts. The club was officially established in 2025 to further strengthen student involvement in chemical energy innovation and the development of green technologies.

The Club becomes a leading platform for student exploration of electrochemical and thermoelectric sustainable energy, with international recognition through global programs and competitions that foster innovation, expertise, and global knowledge sharing.

CHEM-E CAR CLUB

Throughout its establishment , the Chem-E Car Club has involved in many competitions and STEM activities. Among the significant accomplishments of Chem-E Car Club are :

- PTSN Chem-E Car Competition 2023
- UiTM Shah Alam Visit
- STEM Energizer Program (MOSTI)
- PTSN Chem-E Car Competition 2024
- International Chem-E Car Competition (Taylor's University)
- UKM Hydrogen Technology Visit
- Chemistry in Motion (SK Parit Kadzi)
- International Chem-E Car Forum (Universitas Mercu Buana)
- E-MOVE UTHM 2025
- Chem-E Car Student Competition 2025



Chem-E Car Competition 2023



Chemistry in Motion (SK Parit Kadzi)



International Chem-E Car Competition at Taylor's University

ENGINEERING ETHICS

The Earth and Us

Every morning, when we wake up and open our eyes, we see lights fill the space above us. We see the sky stretches wide and blue, calm and endless. Beneath us, the ground feels solid and steady, quietly holding everything in place. We breathe in the air effortlessly without thinking, unaware that this invisible gift has protected lives for years.

Long before we were born, before any human took the first breath, the Earth was already on its journey. Scientists say the Earth formed about 4.6 billion years ago, born from dust, fire, particles, and movement in space. Over millions of years, molten rock cooled, oceans slowly formed, and continents drifted into place. Time moved patiently, shaping mountains, carving valleys, and preparing a home for us to live in. The Earth learnt balance long before we learnt to speak our languages. Thus, this reminds us of something important: the Earth existed long before us, and it will continue to exist long after us. Even though our time here is short, our actions can leave everlasting marks.

“If the entire history of the Earth were encapsulated into a single day, our existence as humans would appear only in the last few seconds before the dawn...”

Humans as Khalifah (Guardians) of the Earth

As our knowledge grows, so does our responsibility. We learn that Allah s.w.t (The Creator) created the Earth with wisdom and then placed humans upon it with a purpose. Humans were not made owners of the Earth but as Khalifah of something precious, which is the Earth.

Think of a Khalifah like a trusted and special guardian of a large and beautiful garden. The Earth is an Amanah, a trust. It is to be used with care, not exhausted without thought. This trust connects belief with action, reminding humans that every choice has consequences.



ENGINEERING ETHICS

Long before humans learnt to build cities or machines, Allah s.w.t (The Creator) declared something very important. In the Qur'an, Allah s.w.t says:

“ ———
Indeed, I will place upon the Earth a Khalifah...
(Surah Al-Baqarah 2:30)

With this one sentence, Allah s.w.t as The Creator gave us (humans) a role unlike any other creation. Humans were not placed on Earth as owners but as Khalifah, the caretakers or guardians. We cannot exhaust every resource on Earth because the Earth is not ours to begin with! Furthermore, we are entrusted by Allah s.w.t to look after it.

As humans, we are given a special gift or 'Aqal to carry this responsibility. 'Aqal is the ability to think, reason, and make choices. Through 'Aqal, we can decide between right or wrong, care or neglect, and responsibility or destruction.

“ ———
And do not cause corruption on the Earth after it has been set in order...
(Surah Al-A'raf 7:56)

This verse is not only about human behaviour but also about decisions. It is about how we as humans use knowledge, power, and technology. Every action taken using the Earth's resources must be guided by thought, wisdom, and self-control.

This means the Earth was not created broken or chaotic. It was beautifully created and well-balanced. We were given 'Aqal so that our actions would protect and preserve this balance and not destroy it.

As human knowledge and understanding of the Earth deepen, we know that the Earth is composed of layers. Deep inside is the core, extremely hot and rich in metals. Above it lies the mantle, slowly moving over millions of years. On the outside is the crust, a thin layer where humans live, farm, build, and travel.



ENGINEERING ETHICS

From this thin crust come the resources humans depend on every day lives : metals for machines, minerals for buildings, oil for fuel and plastic. Above it all is the atmosphere, a thin layer of air that protects life by blocking harmful radiation and keeping the planet warm. Without it, no human would survive a single breath. Everything we use daily begins from the Earth.

“ ***The Prophet Muhammad ﷺ also reminded humanity of this trust when he said: “The world is green and beautiful, and Allah has appointed you as stewards over it.” (Sahih Muslim)*** ”

Knowledge, Power, and Responsibility

As humans learnt science and engineering, our ability to shape the Earth grew stronger. We learnt to extract resources, build machines, and create technologies that improved our daily lives. Cars became faster. Cities grew bigger. Life became more convenient. But not all choices were wise. Smoke polluted the air. Waste covered the land. Rivers became dirty. The Earth, formed carefully over billions of years, began to suffer the consequences of actions taken in only a few generations. This is where 'Aqal matters the most. Knowledge alone is not enough. Without ethics, knowledge can cause harm and destruction.

“ We were gifted with intellect to honour this sacred trust..”

The lifecycle of a car is a journey we share with the Earth.

We begin our journey long before a car ever moves on the road. Before the engine starts and before the wheels turn, the car already has a story. Its story begins deep inside the Earth, where metal sleeps in rocks and oil rests beneath layers of soil. When we decide to build a car, we are not just building a machine. We are asking the Earth to give us part of itself.

As we take metal, oil, and other materials from the Earth, we often do not see the effort it took for these resources to exist. The Earth needed millions of years to form them. Yet we can use them in a single moment. This is why, as Khalifah, we must pause and ask ourselves whether we are taking only what we need, or more than we should. Our journey with the car already tests our sense of responsibility as the Khalifah.

ENGINEERING ETHICS

PITSTOP 1 - RESOURCE EXTRACTION



FACTS

The Earth needed millions of years to form its resources.



Put Your Thinking Cap

What materials from the Earth are needed to build a car ?



A Question of Scale

Why taking too much resources from the Earth can create problems?



The Khalifah's Decision

How should we decide how much material to use?

Building cars with Itqan (Excellence)

When we begin to build the car, our choices multiply. We have the many choices to choose from : the designs, the materials, and the processes. At this stage, remember we used a lot of energy. Materials are extracted, chemicals are mixed. Any small mistakes can create waste, and carelessness can cause harm. This is the stage where Itqan matters the most. When we plan carefully and work with precision, we reduce waste and respect the trust Allah has placed upon us. Planning and executing our design well is not just good engineering practice; it is a good character.

Once the car is ready, we finally see it move. We feel excitement as the wheels turn and the car travels forward. But at this stage, we must ask what the car leaves behind as it moves. Many cars burn fuel and release smoke into the air. That smoke does not disappear, it enters the air we breathe, the skies above us, and the lungs of people and animals. If we cause harm through movement, then our success comes with a hidden cost.

ENGINEERING ETHICS

PITSTOP 2 - MANUFACTURING



FACTS

Engineers choose the designs, materials and processes. Mistakes can create disaster.



Consider this :

What can happen to the car when engineers use bad designs and processes ?



A Question of Scale

Why we must practice Itqan (meticulous for excellence in task) in manufacturing a car ?



The Khalifah's Decision

How can we create Itqan mindset in our daily lives?

Chem-E Car Changes The Story

When we build a Chem-E-Car, we prove that movement does not need pollution. We show that energy can be clean, controlled, and thoughtful. What we design affects not only performance, but health, safety, and the future. As time passes, every car grows old. Parts wear out. Materials weaken. Eventually, the car reaches the end of its working life. At this moment, our responsibility does not end. If we throw everything away, we turn useful materials into waste and add to the burden on the Earth.

But we can choose a better option. We can design cars so they can be taken apart. We can reuse wheels, frames, and components. We can recycle materials and give them new purpose. When we do this, we honour the concept of Amanah. We recognise that the Earth's resources are limited. In this journey, we realise that a car is never just a car. It is a reflection of our values. It shows how we think, how we plan, and how we treat the world around us. Every stage of the car's life; from material extraction to disposal, we must ask ourselves = the same question: are we acting as responsible Khalifah?

ENGINEERING ETHICS

PITSTOP 3 - CAR HIDDEN COST



FACTS

Once the car moved, it burnt fuel and release smoke. The smoke contains harmful substances that polluted the air.



Consider this :

What can happen to humans and animals that breathe the polluted air ?



A Question of Scale

Why we must create car that minimise pollution ?



The Khalifah's Decision

How can we design a car that environmental friendly?

Guardians of the Earth: A Car's Journey, Our Responsibility

The Guiding Principle



1. Material Extraction: A Request to the Earth

- We must take only what we need, honouring the Earth's resources.

2. Manufacturing: Guided by Itqan (Excellence)

- Building with care and precision reduces waste and respects the trust placed in us.



3. In Use: Considering What's Left Behind

- A car's emissions affect the air for all living things; clean engineering protects life.



4. End of Life: A Better Ending

- Our duty doesn't end; we must reuse and recycle materials to honour the trust.

ETHICS & CHEM-E CAR

Chem-E-Car relates closely to Itqan and engineering ethics as it emphasizes safety, environmental responsibility, integrity, accountability, and teamwork. We must prioritise safe chemical selection, proper handling, and risk management to protect ourselves, other users and surroundings. Overall, Chem-E-Car serves as a practical platform for applying ethical principles in chemical engineering in the following areas :

1. Safety & Responsibility

Engineers must protect public safety and the environment by:

- Selecting non-toxic and low-hazard chemicals (e.g. avoid highly corrosive or explosive reagents).
- Proper labeling of instruments, proper storage and disposal of chemicals during preparation and competition.
- Designing systems that fail-proof and safe (no leakage or uncontrolled reactions).

2. Environmental Sustainability

Engineers should minimise environmental harm by:

- Using green chemistry principles (renewable reactants, minimal waste, biodegradable by-products).
- Reducing chemical waste and designing a car with less pollutants during operation.

3. Integrity & Fair Competition

Honesty and fairness in professional practice by:

- Not falsify any data during testing and following competition rules strictly.
- Transparent reporting of methods and results.

4. Accountability & Risk Management

Engineers are responsible for the consequences of their designs by:

- Understanding reaction kinetics and pressure buildup to avoid accidents.
- Performing risk assessments before testing and ready to justify design decisions.

5. Teamwork, Respect & Professional Conduct

Respect colleagues and value diversity of ideas by:

- Fair task distribution within the team and acknowledging contributions of all members.
- Resolving conflicts professionally.

6. Social Impact & Education

Engineers can serve society by:

- Using the project to educate the public about chemical engineering.
- Demonstrating that chemistry can be safe, beneficial, and innovative

Engineering Ethics in Action: The Chem-E Car Challenge

Core Design & Safety Principles

Prioritize Public Safety & Responsibility



Use non-toxic chemicals and design fail-proof systems to prevent accidents.

Professional Conduct & Social Impact

Compete with Integrity & Fairness



Report data honestly and strictly adhere to all competition rules.

Champion Environmental Sustainability



Apply green chemistry principles to minimize waste and avoid releasing pollutants.



Foster Respectful Teamwork

Acknowledge all contributions and resolve conflicts professionally within the team.



Ensure Accountability & Risk Management

Perform risk assessments and be prepared to justify all design decisions.



Educate & Inspire the Public

Demonstrate that chemical engineering can be safe, beneficial, and innovative.

DESIGN & REFLECTION

ACTIVITY 1 : THE MINDFUL CAR ENGINEER

Instructions

You are responsible to design your dream car.

Work in your group. Discuss each question and write short answers.

(Note: There are no “perfect” answers but only thoughtful and responsible ideas.)

PART A: BEFORE THE CAR IS BUILT

1- What materials from the Earth are needed to build a car? List at least three materials.

2- Where do plastics used in cars usually come from?

3- Why do you think taking too much resources from the Earth can be a problem?

4- As Khalifah, how should we decide on how much material to use?

Design Task

Name one recycled or reused material you could use for your Chem-E Car body.

DESIGN & REFLECTION

PART B : MAKING THE CAR

- 1- What types of energy are usually used to manufacture a car?

- 2- What kinds of waste might be produced during car manufacturing?

- 3- Why planning is important before we start building a Chem-E Car?

- 4- How does the Islamic value of Itqan (Excellence) guide us during the building stage?

Quick Check

- 5- When building your Chem-E Car, circle the better option in your building stage:
- Build quickly but waste materials
 - Build carefully and reduce waste

DESIGN & REFLECTION

PART C : USING THE CAR

1- What happens when a petrol car is used every day?

2- How does air pollution affect:

a)Humans

b)Animals

c)Plants

3-How is a Chem-E Car different from a normal petrol car?

4- Which Maqasid al-Shariah is protected when we reduce pollution? You can choose to discuss in the following Maqasid al-Shariah areas : Hifz al-Nafs (Protection of life) / Hifz al-'Aqal (Protection of intelligent) / Hifz al-Mal (Protection of Belongings).

Reflection

Would you want your family to breathe polluted air? Why?

DESIGN & REFLECTION

PART D : END OF LIFE

1-What usually happens to cars when they can no longer be used?

2- Why is throwing everything away considered a waste?

3- What does Amanah (Trust) mean at the end of a car's life?

4- List two parts of car that can be reused or recycled.

Think Like an Engineer

How can we design our Chem-E Car so it creates less waste? You can draw your design and describe your ideas.

DESIGN & REFLECTION

PART E : RECYCLING & NEW LIFE

1- What does recycling mean in simple words?

2- How does recycling help reduce damage to the Earth?

3- What does this sentence mean to you?

“We do not inherit the Earth from our ancestors; we borrow it from our children.”

4- Which Maqasid al-Shariah is most related to protecting future generations?

DESIGN & REFLECTION

PART F : FUTURE THINKING

Draw & Label

Draw the life cycle of a car:

Materials → Building → Using → Old Car → Recycling

Label one ethical action at each stage.

Pledge

Finish the sentence:

“As a Chem-E Car engineer, I promise to _____.”

TECHNICAL SECTION

Energy Change and Conversion in the Chem-E Car

The Chem-E Car is an educational model designed to demonstrate the fundamental principles of energy transformation. It operates by converting stored chemical and thermal energy into electrical energy, which is ultimately transformed into mechanical energy to create motion.

Think of energy conversion in the Chem-E Car like a currency exchange at an airport. You start with one currency (Chemical Energy), exchange it at a kiosk for a different currency (Electrical Energy), and finally use that cash to purchase a taxi ride (Mechanical Energy). The value (energy) is not created or destroyed; it simply changes forms to get you where you need to go. Chem-E Car utilizes two distinct methods to achieve this propulsion:

1. Electrochemical Energy Conversion (Galvanic Cell)

This method relies on a spontaneous redox reaction within a galvanic cell. When magnesium (Mg) and copper (Cu) electrodes are placed in a copper(II) sulfate electrolyte, chemical energy is released.

The Process:

Oxidation occurs at the magnesium anode $\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^-$
and

Reduction occurs at the copper cathode $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu(s)}$

The Flow:

This reaction forces electrons to flow through an external circuit, converting Chemical Energy directly into Electrical Energy. This electricity powers a DC motor, which converts the energy into Mechanical Energy to drive the car.

Energy Change:

Chemical Energy \rightarrow Electrical Energy \rightarrow Mechanical Energy

TECHNICAL SECTION

Chemical energy stored in the magnesium, copper, and electrolyte is released through oxidation and reduction. Connecting multiple cells in series increases the voltage and current output. You can view the galvanic cell like a dam. The water stored behind the dam represents the Chemical Energy (potential) held in the magnesium. When you open the floodgates (complete the circuit), the water rushes down; this flow is the Electrical Energy. Finally, the rushing water hits a turbine and spins it; this is the Mechanical Energy that actually does the work of moving the car.

2. Thermoelectric Energy Conversion

This method utilizes a Thermoelectric Generator (TEG) to exploit temperature differentials.

The Process:

A candle burns hydrocarbon wax (releasing chemical energy as heat) to create a heat source, while ice provides a cold source.

The Flow:

The TEG converts this thermal difference into electricity.

Energy Change:

Chemical Energy → Thermal Energy → Electrical Energy → Mechanical Energy

You can think of the temperature difference in a TEG like a waterfall. Just as water needs a height difference (high ground to low ground) to flow and turn a water wheel, a thermoelectric generator needs a thermal difference (high heat to freezing cold) to push electrons and generate the electricity needed to power the motor.

TECHNICAL SECTION

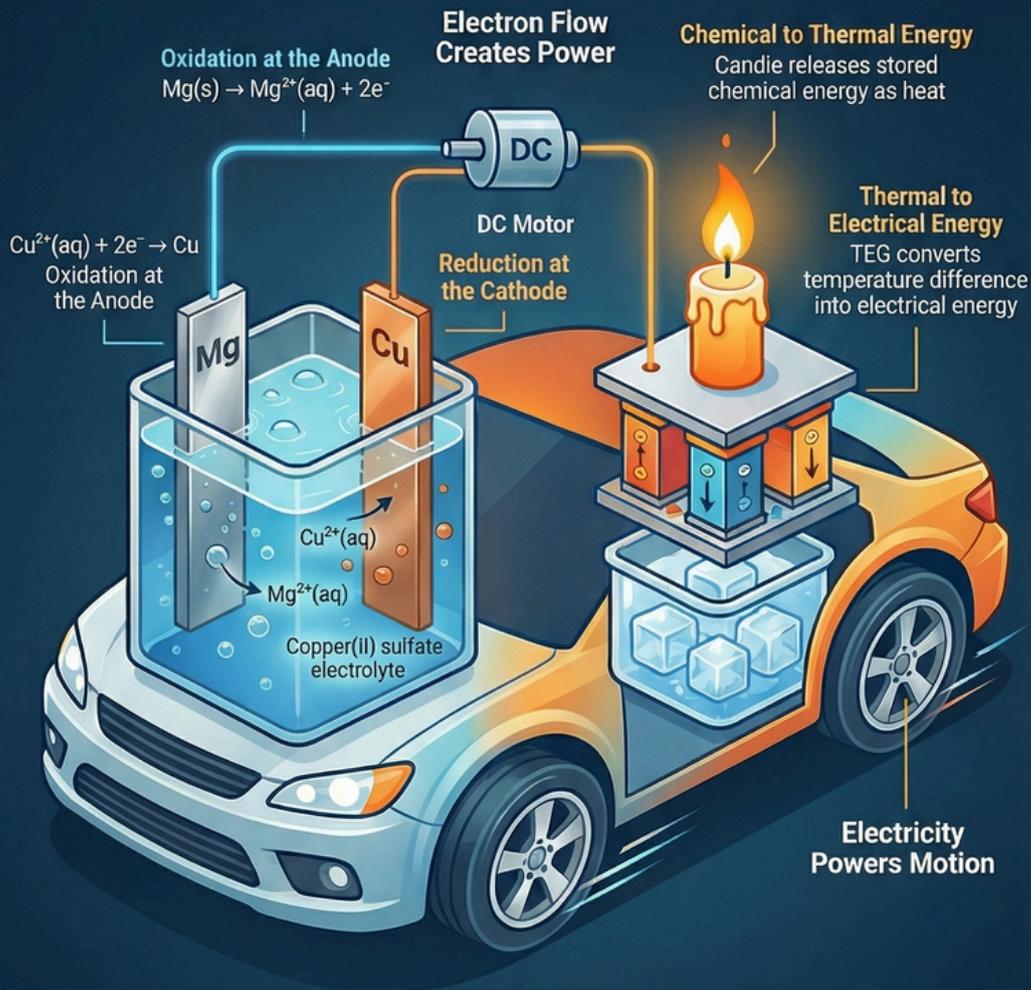
Chem-E Car: A Journey of Energy Conversion

Method 1: Electrochemical Conversion (Galvanic Cell)

How It Works:
A Spontaneous Redox Reaction

Method 2: Thermoelectric Conversion (TEG)

How It Works:
Using a Temperature Difference



Energy Transformation Path



Chemical Energy



Electrical Energy



Mechanical Energy

Energy Transformation Path



Chemical Energy



Thermal Energy



Electrical Energy



Mechanical Energy

Conclusion: Two Paths to Motion

Summary of Energy Conversions: The Chem-E Car effectively demonstrates two primary pathways for converting stored energy into motion.

A Showcase of Engineering Principles: These transformations highlight fundamental principles of energy change and efficiency applied in real-world engineering.

TECHNICAL SECTION

INTRODUCTION

The Chem-E Car is designed to inspire and challenge students to conceptualise, design, and build a compact, shoebox-sized vehicle powered entirely by a chemical energy source. Participants are evaluated not only on their car's performance in completing specific, predefined tasks but also on the originality and innovation demonstrated in their design. Furthermore, careful attention is given to factors such as safety, environmental impact, and health considerations, encouraging students to develop solutions that are both efficient and responsible. This multifaceted approach nurtures creativity, critical thinking, and practical problem-solving skills, equipping students to tackle real-world engineering challenges.



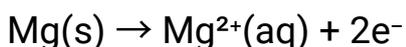
TECHNICAL SECTION

STEMOBILE ; ECO - FRIENDLY CAR POWERED BY REACTIONS

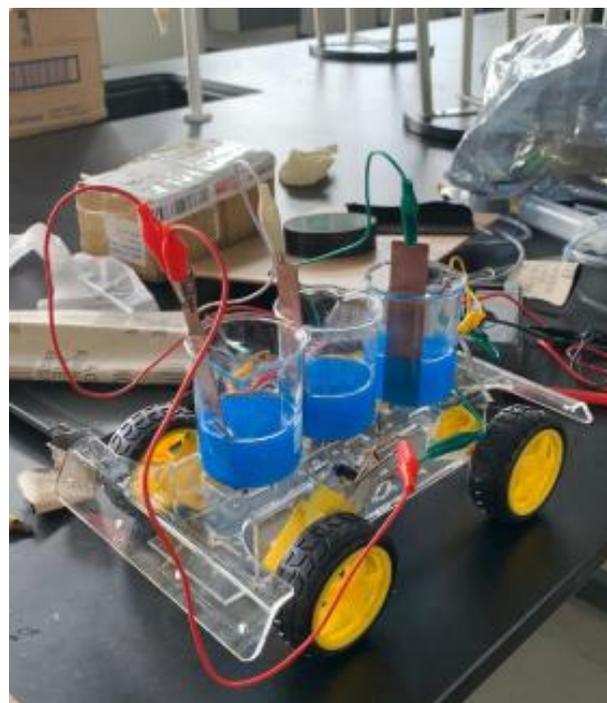
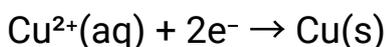
WORKING PRINCIPLE

The Chem-E Car cell functions based on galvanic (electrochemical) reaction principles. When the magnesium (anode) and copper (cathode) electrodes are immersed in the copper(II) sulfate (CuSO_4) electrolyte, a spontaneous redox reaction occurs which is oxidation and reduction involve.

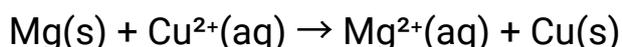
At the anode (oxidation):



At the cathode (reduction):



The flow of electrons from magnesium to copper through the external circuit produces electrical energy, which powers the motor of the Chem-E Car. The overall cell reaction is:



ENERGY SOURCE

The energy source of the Chem-E Car is the chemical energy stored within the magnesium and copper materials and the CuSO_4 electrolyte. Through oxidation and reduction reactions, this chemical energy is converted directly into electrical energy. By connecting multiple cells in series, the output voltage and current are increased to produce sufficient power to drive a DC motor.

TECHNICAL SECTION

PROCEDURE: PREPARATION AND SET UP OF CHEM-E CAR CELL

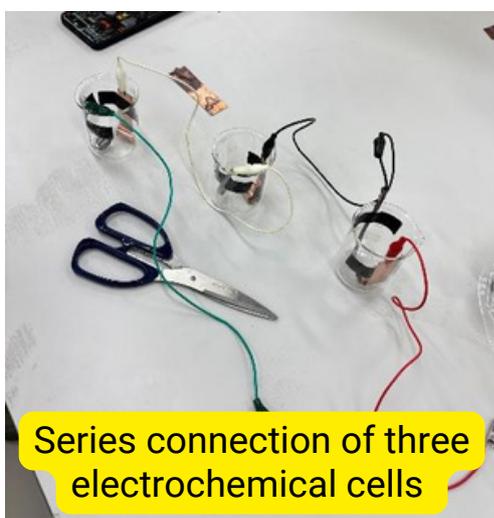
Tools and Apparatus

1. Glass rod
2. Volumetric flask 250 mL
3. 1 Beaker 100 mL
4. 1 Beaker 150 mL
5. 2 Alligator clips
6. Electrical tape
7. 800-grit sandpaper
8. 1000-grit sandpaper
9. Electronic balance
10. Funnel

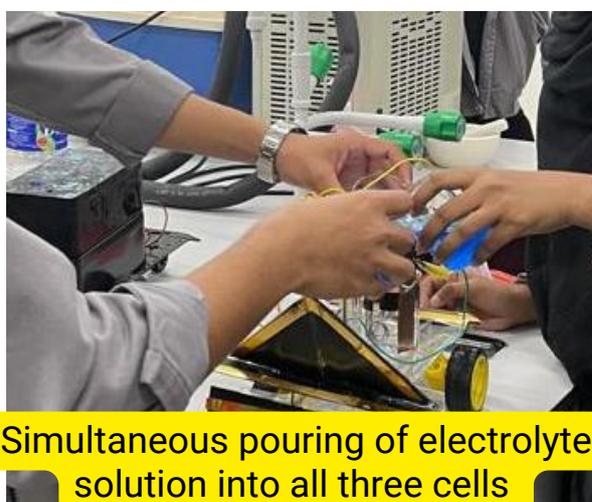
Materials

1. Copper(II) sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)
2. Magnesium strips (10–15 cm length each)
3. Copper plates (0.5 mm thickness)
4. Distilled water 100 ml
5. Aluminium foil

Experimental Setup of Electrochemical Cell System



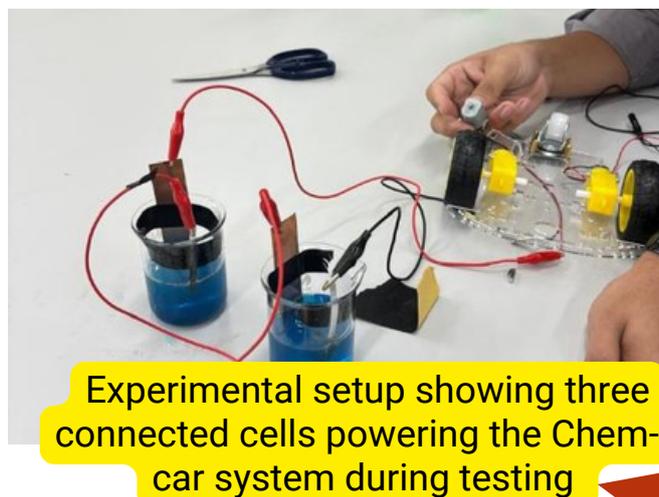
Series connection of three electrochemical cells



Simultaneous pouring of electrolyte solution into all three cells

Note :

To start a testing, pour only 50-60 ml into the 100 ml beaker. Increase the surface area is the key.



Experimental setup showing three connected cells powering the Chem-E car system during testing

TECHNICAL SECTION

A. Preparation of Electrolyte Solution

1. Weight 49.94g of copper(II) sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) using an electronic balance.
2. Add 100mL of distilled water into the 150 ml beaker.
3. Stir the mixture with a glass rod until all CuSO_4 crystals are completely dissolved to form a 2 M CuSO_4 solution.
4. Pour the prepared solution carefully into a volumetric flask using funnel and label it
5. Cover the flask with aluminium foil to prevent contamination and light exposure.

B. Preparation of Electrodes

6. Using 800-grit sandpaper, gently polish the copper plate to remove any oxide layer and obtain a smooth, clean surface.
7. Using 1000-grit sandpaper, lightly sand the magnesium strip (10–15 cm). Avoid excessive sanding to prevent material loss.
8. Secure both electrodes in a 100 mL beaker using electrical tape
9. Ensuring it properly positioned and not touching each other.
10. Repeat the same procedure for all three cells.

C. Assembly of the Chem-E Car Cell

11. Simultaneously pour the prepared CuSO_4 solution into all three electrode beakers at the same time.
12. Connect the magnesium (Mg) electrode of the first beaker to the copper (Cu) electrode of the second beaker using alligator clips.
13. Continue connecting the remaining cells in a series configuration like $\text{Mg} \rightarrow \text{Cu} \rightarrow \text{Mg} \rightarrow \text{Cu}$.
14. Connect the magnesium electrode negative terminal) of the last cell to the negative terminal of the motor.
15. Connect the copper electrode (positive terminal) of the first cell to the positive terminal

LEARNING CHECK

1. Why is distilled water used in preparing the CuSO_4 solution?
 - A. It is cheaper
 - B. It contains no impurities that may affect the reaction
 - C. It increases the solution color
 - D. It reacts with CuSO_4
2. What is the purpose of stirring the CuSO_4 solution?
 - A. To heat the solution
 - B. To change the concentration
 - C. To help dissolve the CuSO_4 completely
 - D. To evaporate water
3. Why is the solution transferred into a volumetric flask?
 - A. For heating
 - B. For accurate volume measurement and storage
 - C. For faster reaction
 - D. For decoration
4. Why is the flask covered with aluminum foil?
 - A. To cool the solution
 - B. To prevent spilling
 - C. To protect the solution from light and contamination
 - D. To increase conductivity
5. Why is the copper plate polished before use?
 - A. To make it shiny
 - B. To remove oxide layers and improve conductivity
 - C. To reduce its size
 - D. To prevent corrosion

LEARNING CHECK

6. Why should the magnesium strip not be sanded excessively?
 - A. It may rust
 - B. It may lose too much material
 - C. It becomes heavier
 - D. It reacts with sandpaper

7. Why must the electrodes not touch each other in the beaker?
 - A. To save space
 - B. To prevent short-circuiting
 - C. To improve appearance
 - D. To increase voltage

8. Why are the cells connected in series?
 - A. To reduce current
 - B. To increase voltage
 - C. To stop the reaction
 - D. To save materials

9. Which electrode acts as the negative terminal in the cell?
 - A. Copper
 - B. CuSO_4
 - C. Magnesium
 - D. Water

10. What would likely happen if one cell is connected incorrectly?
 - A. The motor will run faster
 - B. Nothing will change
 - C. The motor may not run or run poorly
 - D. The solution will evaporate

TECHNICAL SECTION

FROM HEAT TO WHEEL : A TEG POWERED CHEM-E CAR

WORKING PRINCIPLE

The Chem-E-Car operates using a thermoelectric generator system that converts chemical and thermal energy into motion. A candle is used as the heat source, while ice is placed on the cold side. The temperature difference generates electrical energy, which powers a direct current motor and moves the car forward.



ENERGY SOURCE

The candle burns hydrocarbon wax and produces thermal energy. This thermal energy is converted into electrical energy by the thermoelectric generator through the Seebeck effect.

PROCEDURE: PREPARATION AND OPERATION OF CHEM-E-CAR

Tools and Apparatus:

- DC motor
- Wheels and car chassis
- Candle and candle holder
- Ice container / cold-side heat sink
- Connecting
- Wires
- Electrical tape
- Multimeter (for voltage checking)

Materials:

- Candle (hydrocarbon-based wax)
- Ice
- Thermoelectric Generator (TEG)

TECHNICAL SECTION

A. Preparation of the Thermoelectric Power System:

1. The thermoelectric generator (TEG) is mounted securely on the car chassis using an insulated holder to prevent heat loss and vibration.
2. The hot side of the TEG is positioned directly above a candle flame to ensure continuous heat supply.
3. The cold side of the TEG is attached to a container filled with ice to maintain a low temperature surface.
4. Electrical wires are connected from the TEG terminals to the DC motor using proper insulation.
5. A switch is installed between the TEG and the motor to control the start of the car.
6. The temperature difference between the hot and cold sides is verified to ensure sufficient voltage generation.

B. Assembly and Operation of the Chem-E Car:

1. Before operation, ice was placed on the cold side container of the thermoelectric generator, and a candle was positioned below the hot side.
2. The candle is ignited to create a temperature difference between the hot and cold sides of the thermoelectric generator.
3. Different temperature caused the thermoelectric generator to produce electrical energy, which was supplied to the direct current motor.
4. The electrical energy powered the motor, causing the wheels to rotate and the car to move forward.

LEARNING CHECK

1. Why is the thermoelectric generator (TEG) mounted securely on the car chassis?
 - A. To improve appearance
 - B. To prevent vibration and heat loss
 - C. To increase weight
 - D. To reduce voltage
2. What is the purpose of using an insulated holder for the TEG?
 - A. To increase electrical resistance
 - B. To prevent heat loss and protect components
 - C. To cool the hot side
 - D. To hold the ice container
3. Why is the hot side of the TEG placed directly above the candle flame?
 - A. To reduce energy loss
 - B. To maintain a constant heat source
 - C. To melt the ice faster
 - D. To protect the motor
4. What is the role of the ice attached to the cold side of the TEG?
 - A. To increase electrical resistance
 - B. To raise the temperature
 - C. To maintain a low temperature surface
 - D. To power the motor
5. Why is it important to verify the temperature difference between the hot and cold sides?
 - A. To improve wheel alignment
 - B. To ensure sufficient voltage generation
 - C. To reduce candle size
 - D. To prevent motor overheating

LEARNING CHECK

6. Why must electrical wires connected to the TEG be properly insulated?
 - A. To improve color coding
 - B. To prevent short circuits and energy loss
 - C. To increase voltage
 - D. To reduce temperature difference

7. What is the function of the switch installed between the TEG and the motor?
 - A. To change voltage polarity
 - B. To control the start and stop of the car
 - C. To increase current
 - D. To cool the TEG

8. Why is ice added to the cold side before operating the Chem-E car?
 - A. To decorate the setup
 - B. To maintain a large temperature difference
 - C. To reduce friction
 - D. To increase car weight

9. What does happen when the candle is ignited?
 - A. The motor cools down
 - B. Electrical wires melt
 - C. A temperature difference is created across the TEG
 - D. The wheels stop moving

10. What are the causes of thermoelectric generator to produce electrical energy?
 - A. Chemical reaction
 - B. Mechanical motion
 - C. Temperature difference between hot and cold sides
 - D. Light energy

LEARNING CHECK

11. What is the energy conversion occurs in the thermoelectric generator?
 - A. Electrical to chemical
 - B. Thermal to electrical
 - C. Mechanical to thermal
 - D. Chemical to mechanical

12. How does the generated electrical energy moved the car?
 - A. It heats the wheels
 - B. It powers the DC motor, rotating the wheels
 - C. It melts the ice
 - D. It ignites the candle

13. What would most likely happen if the candle flame goes out during operation?
 - A. The motor speed increases
 - B. The voltage output decreases or stops
 - C. The ice melts faster
 - D. The wheels rotate backward

14. How would reducing the temperature difference affect the car's motion?
 - A. The car moves faster
 - B. The voltage increases
 - C. The motor produces less power
 - D. The wheels lock

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