ENVIHEI

Title of the PBL challenge: **Radiation, power losses, and responsible consumption: Exploring energy efficiency through Electromagnetism**

Name of the responsible lecturer

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University / Department / Degree program

University of León / Department of Applied Chemistry and Physics / Bachelor's Degree in Computer Engineering

Course / Subject in which implemented

1st Course / Physics

Implementation period (dates)

September 29, 2025 – December 3, 2025

Total duration (weeks/hours)

4 weeks / 40 hours

Number of students involved

106 students

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1. Project Design

1.1 Brief description of the project and the challenge proposed

The project aims to enable students to explore how circuit design decisions affect energy dissipation through heat and the responsible use of resources, utilizing Multisim for circuit simulation. The central challenge addresses how heat generated in components (resistors, inductors) not only increases energy consumption but also reduces material durability and generates electronic waste (e-waste), linking directly to SDG 12 (Responsible Consumption and Production).

1.2 Expected learning outcomes (academic and transversal competences)

- To comprehend the link between resistive losses, efficiency, and responsible consumption.
- To apply electromagnetic principles to the design of efficient circuits.
- To utilise Multisim for rigorous technical analysis.
- To develop critical thinking, sustainability-driven mindsets, and communication skills.
- To formulate engineering proposals aligned with SDG 12.

1.3 Targeted sustainability competences

The project fosters systems-thinking and strategic action for sustainability. Specifically, it encourages students to understand that sustainable hardware design begins with a profound grasp of circuit physics, and that system efficiency constitutes an ethical commitment to responsible consumption. It develops the capacity to link technical concepts (Ohm's Law, Power) with global impacts (e-waste).

1.4 Sustainability approach and how it is integrated into the project

The sustainability framework is integrated through SDG 12:

- **Integration**: Students are taught that heat in circuits is not merely an engineering hurdle but a sustainability issue: increased heat implies lower efficiency, shorter component lifespans, and consequently, higher e-waste and increased natural resource extraction.
- **Application**: Students must demonstrate how technical optimisation (e.g., resonance in RLC circuits) minimises heat loss and reduces the need for active cooling, thereby supporting the circular economy.

1.5 Methodologies and tools used (PBL structure, facilitation techniques, etc.)

- **Problem-Based Learning (PBL)**: The project is structured around a parametric optimisation challenge. Students are presented with an inefficient circuit and must identify the causes of energy dissipation. Learning focuses on the students' ability to evaluate component impact and determine how adjusting specific parameters (frequency, inductance, or capacitance) achieves resonance, transforming an inefficient system into one aligned with SDG 12 sustainability standards.
- **Simulation**: Multisim is used as a virtual laboratory for experimentation. This tool allows students to modify variables and observe the immediate impact on power transfer and thermal loss reduction, facilitating a "trial-and-error" cycle that would be prohibitively costly and slow in a physical environment.
- **Facilitation**: The lecturer acts as a technical guide and supervisor of the inquiry process. Through questioning, students are guided not only towards a numerical result but towards a reflection on the physical

interpretation of data and their ethical responsibility in efficient hardware design.

- **Collaborative Work**: Students work in teams using shared digital tools for result synthesis, fostering the testing of hypotheses regarding which parametric changes offer the optimum balance between performance and sustainability.

1.6 Organization of the project (group formation, timeline, milestones)

The project is conducted over several 2-hour sessions:

1. Presentation of the link between thermal loss and sustainability, and exploration of the Multisim interface.
2. Formulation of research questions and hypotheses by the students.
3. Measurement and parametric optimisation.
4. Synthesis of results and submission of the technical laboratory report.

1.7 Deliverables requested from students (type, format, deadlines)

Students were required to submit their work through the course's Virtual Campus, with a deadline of one week after the assignment was given.

Type of deliverables:

- **Technical Laboratory Report**: Must include responses to the SDG 12 critical analysis and technical justification of the implemented improvements.
- **Simulation Files**: The final optimised circuit design in its native format, ready for execution and verification.

Format of deliverables:

- **Report**: Digital file in Word or PDF format.

- **Simulations**: Files with a .ms14 extension (or the corresponding Multisim version).

1.8 External collaborators involved (mentors, companies, experts...) and their role

The supervisor acts as the primary mentor throughout the activity, providing students with technical orientation, guidance, and support, particularly in relation to the analysis of losses and the identification of potential improvements. Rather than providing direct solutions, the supervisor supports students in interpreting the technical information, evaluating different alternatives, and making informed decisions during the optimisation process. This approach encourages students to take an active and progressively autonomous role in the development of the proposed solution.

2. Project Evaluation

2.1 Assessment criteria and methods used

Evaluation is based on a rubric comprising four pillars:

- Technical quality of the circuit designs (25 %).
- Consistency and rigour in the analysis of losses (25 %).
- Originality and feasibility of the proposals (25 %).
- Clarity and precision of the final report (25 %).

2.2 Evidence of student learning (examples, outputs, results)

Evidence is provided through a "Results" document, which includes anonymised student responses accompanied by qualitative assessments and statistical outcomes of the cohort's performance.

3. Reflections and Recommendations

3.1 Main achievements and strengths of the project

- The project successfully transcended traditional circuit teaching by connecting it to current climate challenges. By linking principles such as Ohm's Law and resonance with SDG 12, students understood that energy efficiency is an ethical and environmental imperative.
- The PBL methodology transformed the student's role from a passive recipient of information to a critical designer. Students demonstrated a remarkable capacity for efficiency-based decision-making.
- The ability to quantify and visually represent results facilitated a deep understanding of the relationship between electromagnetism and sustainability.

3.2 Challenges faced and how they were addressed

Challenge: Preventing the cognitive load of technical learning (reactive power calculations, resonance, and Multisim proficiency) from overshadowing the critical analysis of sustainability.

Solution: Strategic questioning was employed during design phases. By presenting real-world dilemmas (e.g., the trade-off between hardware performance and thermal impact), technical calculation was reframed as a necessary tool for achieving an ethical solution.

Challenge: The transition from direct instruction to guided learning caused initial friction among students accustomed to passive content reception. Resistance to pedagogical autonomy was observed, manifested in requests for traditional formats (e.g., "closed-answer" presentations).

Solution: This was addressed by explicitly explaining the value of uncertainty and autonomy in engineering training. Rather than providing pre-configured solutions, facilitation techniques were used to transform requests for answers into new lines of inquiry.

3.3 Lessons learned for future implementations

Student autonomy in PBL environments is proportional to the robustness of the initial support. Future iterations should strengthen procedural scaffolding (Multisim guides) and conceptual scaffolding (RLC analysis frameworks).

Project success depends heavily on the problem identification phase. Dedicating sufficient time for students to internalise the socio-technical relevance of the challenge is vital.

There is a need for a more explicit methodological induction at the start of the term to mitigate resistance to change and align expectations regarding self-directed learning.

4. Supporting Material

4.1 Lecturers' materials and project documentation

Lecturers' materials and project documentation are available in the following link:

https://drive.google.com/drive/folders/1NLj9t-oblToAJ6pDS5vHkagz-5wnGh7f?usp=drive_link

4.2 Deliverables produced by students, final presentations or pitch materials

An example of deliverables produced by students are available in the following link:

https://drive.google.com/drive/folders/1OhfJexrR4_aM-oKBXWcw_OezflgKFMT0?usp=drive_link

4.3 Images/videos (with consent)

Photographic and video records were captured with the explicit consent of the participating students, and are available in the following link: https://drive.google.com/drive/folders/1dcAlWrv_UjhDbERvNqt6OclL8jw-PEXV?usp=drive_link

4.4 Any other relevant material

All the materials, including this report, are available in the following link: https://drive.google.com/drive/folders/1PjHcocASw_CVBx6Mbykxz1B2UYCqwdmR?usp=drive_link