DATASET DETAILS

This document details the dataset collected and used in the paper "Benchmarking Large Language Models on Homework Assessment and Feedback in Circuit Analysis". The directory tree of the dataset is shown in Fig. 1.

```
root
├── electric_circuit_variables_and_elements
│   ├── q_010502_cs_5
│   │   ├── raw_official_solution.txt
│   │   ├── official_solution.pdf
│   │   ├── handwritten_student_solution.png
│   │   ├── raw_student_solution.txt
│   │   ├── student_solution.pdf
│   │   ├── final_answer.txt
│   │   └── responses
│   │       ├── gpt-3.5-turbo-0125
│   │       │   ├── response.txt
│   │       │   └── response.pdf
│   │       ├── gpt-4o-2024-05-13
│   │       └── llama3-70b-instruct
│   ├── q_010502_ws_31
│   ├── q_010503_cs_7
│   └── ...
├── analysis_of_resistive_circuits
├── the_operational_amplifier
├── the_complete_response_of_circuits_with_energy_storage_elements
├── sinusoidal_steady_state_analysis
├── frequency_response
└── prompt_template.txt
```

Fig. 1. Directory tree of the dataset

The basic elements in the dataset are structured based on different students' solutions to the associated problems. The problems in our dataset are all from the textbook [1], and the students' solutions are collected from a circuit analysis course for undergraduates involving 37 students in the School of Electrical and Computer Engineering. The folders of these basic elements are named with the following method, in which we take `q_010502_cs_5` as an example to illustrate.

Table 1. Problem indexes and number of data in each topic

Topic	Problem Indexes	Number of Data
Electric Circuit Variables and Elements	1.x-x, 2.x-x	40
Analysis of Resistive Circuits	3.x-x, 4.x-x, 5.x-x	63
The Operational Amplifier	6.x-x	28
The Complete Response of Circuits With Energy Storage Elements	7.x-x, 8.x-x, 9.x-x	95
Sinusoidal Steady-State Analysis	10.x-x	29
Frequency Response	13.x-x	28

* "x" represents the index of either a section or a problem in a section.

i) In this example, "`q_010502`" means that the corresponding problem is Problem 1.5-2 in [1]. Specifically, the codes "`01`" and "`05`" indicate the chapter and section indexes, respectively, while "`02`" is the problem index in the section.

ii) The code "`cs_5`" indicates that the included student's solution in the folder `q_010502_cs_5` is from the student with index 5. The student indices are mainly for our internal use to track the original documents of students' solutions. They are de-identified and consistently used across different problems. Additionally, "`cs`" implies that student 5's solution is considered correct in all metrics. We use the code "`ws`" to represent the students' solutions that have errors in at least one metric out of the five considered. For example, "`q_010502_ws_31`" indicates that the solution from student 31 solves Problem 1.5-2 in [1] with at least one error in one aspect.

We categorize these elementary folders into 6 topic folders for a clearer structure consistent with the subsections in Section 3.1 of the paper. The relationships between the topics and problem indices in [1] are shown in Table 1, with descriptions of the topics and problems presented in Table 2.

The following data are included in the basic data folder like `q_010502_cs_5`.

- `raw_official_solution.txt`: This file contains the official solution to the corresponding problem in LaTeX format. The contents of this file are inserted in the LLM prompt when we leverage LLMs to assess the students' homework and generate feedback.
- `official_solution.pdf`: For a better reading experience, we generated a PDF file corresponding to the official solution `raw_official_solution.txt`.
- `handwritten_student_solution.png`: This is the original source file of the student's solution. To test the capabilities of LLMs in homework assessment and feedback generation, we converted this image to a LaTeX document using the Mathpix snipping tool. The converted results are saved in the file `raw_student_solution.txt`.
- `raw_student_solution.txt`: This file contains the student's solution in LaTeX format. The contents of this file are included in the prompt and evaluated by the tested LLMs.
- `student_solution.pdf`: For a better reading experience, we generated a PDF file corresponding to the student's solution `raw_student_solution.txt`.
- `final_answer.txt`: This file contains a short summary of the final answer to the corresponding problem. Comparing final answers is an easy task for the LLM, and a student's incorrect final answer may motivate the LLM to identify where the student made the error. The contents of this file are also included as part of the LLM prompt.
- `responses`: This file consists of the responses from the three LLMs evaluated in this paper. The evaluation results are structured into three subfolders: `gpt-3.5-turbo-0125`, `gpt-4o-2024-05-13`, and `llama3-70b-instruct`,

Table 2. Topic descriptions and problem descriptions

Topic	Description	Problem Characteristics
Var. & Ele.	Electric circuit variables and elements are basic concepts in circuit analysis. Students are expected to learn fundamental circuit concepts such as current, voltage, power, energy, and systems of units.	The problems in this topic typically require students to perform basic circuit calculations. For example, students may be asked to calculate a voltage value using Ohm's law. To assess the students' homework and provide feedback effectively, the LLMs being evaluated need to possess knowledge of basic circuit variables and elements.
Resist. Cir.	The resistive circuit is one of the fundamental types of electrical circuits in which all circuit power is dissipated by resistors. A resistive circuit may consist of resistors and independent or dependent voltage and current sources, but not energy storage elements like capacitors and inductors. The key concepts that students need to learn in the analysis of resistive circuits include Kirchhoff's laws (KCL and KVL), series and parallel circuits, node voltage analysis, and mesh current analysis.	The students are typically asked to determine the values of resistances, currents, voltages, or powers of certain elements in given circuits. The final answers are typically numeric values with appropriate units in these cases. In order to provide reasonable feedback, the evaluated LLMs are required to understand the basic circuit analysis methods and be able to do some basic algebraic manipulations.
Op. Amp.	The operational amplifier is a type of circuit element that can be used to build a circuit to perform mathematical operations. In our circuit analysis course, we mainly consider the ideal operational amplifier, which is characterized by having zero input currents and equal node voltages at its input terminals.	The homework problems in this topic typically require students to analyze circuits containing ideal operational amplifiers. The final answers may be in the form of current values, voltage values, or the gain of the circuit, which are numerical values with or without units. These problems test the LLM's ability to understand circuits with more advanced elements like the operational amplifier.
Com. Resp.	The capacitor and the inductor are two basic energy storage elements. Since the constitutive equations of the capacitor and the inductor involve either differentiation or integration, differential equations are required to represent the circuit behaviors with these two energy storage elements. In the considered circuit analysis course, the key points in this topic include the basic properties, series and parallel connections of capacitors and inductors, the initial conditions in a switched circuit, and the complete responses of first-order or second-order circuits.	The problems in this topic involve more advanced devices and more complicated mathematical analyses. The currents or voltages in the circuits might be dynamic instead of static, meaning their values depend on time. The homework problems might ask for dynamic currents or voltages when $t > 0$, differential equations for provided circuits, or inferences of device parameters (e.g., the capacitance of a certain capacitor) given circuit responses. To generate reasonable feedback, the LLMs need to understand different mathematical expressions, recognize differential equations, and perform higher-level mathematical calculations.
Sinusoidal	The circuits considered in this topic are linear circuits with sinusoidal current or voltage sources. In this case, if there is only one sinusoidal source, the circuit response at its steady state will be a sine wave with the same frequency as the input. When there are multiple sources, we can use the principle of superposition to obtain the response. Students are expected to learn the behaviors of circuits that consist of one or more sinusoidal sources, the two representations (i.e., the sinusoid and the phasor) of a sinusoidal signal, the concept of impedance, and the use of basic circuit analysis methods (e.g., KCL and KVL) in the scenarios of sinusoidal steady-state analysis.	Most problems in this topic ask students to calculate the current or voltage responses of circuits with sinusoidal sources. Additionally, some problems may require students to infer the impedance of a particular component. To make reasonable assessments, the tested LLMs need to understand not only the basic circuit principles and analysis methods but also the knowledge related to sinusoidal steady-state analysis, such as the conversions and calculations of sinusoidal time-domain values and phasors.
Freq. Resp.	Based on the sinusoidal steady-state analysis, we can calculate the gain, phase shift, and network function of a linear circuit when there is a sinusoidal current or voltage input source. The frequency response is an equation that represents the gain and phase shift from the input to the output of a circuit. Apart from the formula representations, Bode plots are often used to visualize the frequency responses.	In our considered circuit analysis course, the problems about frequency responses typically ask students to either calculate the network function or draw a Bode plot for a given circuit. Students may also be required to infer some device parameters, such as the capacitance of a capacitor or the resistance of a resistor. The considered LLMs should be able to compare different network functions in terms of both their forms and coefficients and provide reasonable feedback if the student's solution is incorrect. Due to the limited capacity of LLMs for image recognition, we do not ask the LLMs to assess Bode plots.

* ① Var. & Ele. = Electric Circuit Variables and Elements; ② Resist. Cir. = Analysis of Resistive Circuits; ③ Op. Amp. = The Operational Amplifier; ④ Com. Resp. = The Complete Response of Circuits With Energy Storage Elements; ⑤ Sinusoidal = Sinusoidal Steady-State Analysis; ⑥ Freq. Resp. = Frequency Response.

according to the models. Each subfolder contains two files: `response.txt`, which saves the direct LLM output, and `response.pdf`, which is the corresponding PDF file of `response.txt` for a better reading experience. The evaluation classification results are obtained by human inspection based on the file `response.pdf`.

REFERENCES

[1] James A Svoboda and Richard C Dorf. 2013. *Introduction to Electric Circuits (9th Edition).* John Wiley & Sons.