Electrical resistance meter in physics laboratory for engineers

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Abstract. Electrical resistance meter is the key tool in physics laboratory such as electricity meter experiment or DC power band experiment. The aim of this research is to design and develop electrical resistance meter for using in physics laboratory and to find the efficiency of the electrical resistance meter that has been created. The sample are students of Department of Electromechanic Manufacturing Engineering, Bansomdejchaopraya Rajabhat University. The Arduino microcontroller board is used for controlling the electrical resistance meter and finding the electrical resistance meter values, we use the principle of voltage division for the calculation with 24 resistance values. It is explored that the electrical resistance meter can actually be usable with high accuracy, which divided into 3 parts: 1) the percentage difference and the display result of the electrical resistance meter does not exceed 2 percent when compared with the Fluke 115 multimeter, 2) the evaluation by experts found that suitability of the electrical resistant meter has the average score of 3.96 which is at high level and 3) the satisfaction evaluation from the students of the electrical resistance meter has the average score of 4.01 which was also at high level.

1. Introduction
Physics is an important science subject. Learning physics covers the content about natural phenomena from the past to the future; however, the difficulty in physics learning are using formulas for calculating the phenomenon, drawing, explaining the situation, comparing calculated results to the experimental results, analysing the results, and summarizing the experiment. In physics study includes both theory and practice, therefore, effective learning must emphasize on scientific skills in order to make students able to practise the real experience in order to have knowledge with the guidelines by lecturers, especially in the physics laboratory subject [1-2]. Moreover, the lecturers must have learning management, which enable their students to connect the relation between theories and practice from experiments, the students have to make assumptions of the experiments and plan them correctly and appropriately in order to conduct those experiments with accurate results and summaries [3].

From the bachelor's degree curriculum, Department of Electromechanic Manufacturing Engineering, Bansomdejchaopraya Rajabhat University, physics laboratory for engineers subject focus on electricity since it provides students with both knowledge and practical skills that and can be applied to various subjects in their studies by using materials and electrical tools in experimental sets. In the experimental lab, to collect the experimental data, the electrical measuring tools are important part of all quantitative measurement such as a multimeter, which if used for a long time can cause the contacted resistance between the connector and the cable that will affect uncertainty of measurement [4]. Moreover, electrical measuring tools are quite expensive and not enough to use in the laboratory experiment. At present, the technology that used to create electrical resistance meter using the Arduino board as a processor,
executing and using sensors or using techniques such as the kelvin double bridge method, ammeter voltmeter method or DMM two wire connection \[5\] and since some of the students have colour vision impairments, which medically, colour blindness cannot be cured, typically will not able to see red and green colour (red-green blindness) and not able to differentiate green and red colour from other colours as reading the colour bands of each resistor and the order of the colours will define different meaning, also the students are not well versed in memorizing the colour code tables of type 4 and 5 resistors. As a result, electrical quantity calculations in various circuits can be erratic and may result in the students getting lower grades on the topic. Measuring instruments used nowadays may also be obsolete and can reduce the interest of the students; thus, it is necessary to incorporate modern technology into teaching \[6\], which start to have important role in physics laboratory subject.

Therefore, to continue studying physics laboratory with more efficiency, this research has the idea of designing and developing an electrical resistance meter for using in physics laboratory subject for engineers which this electrical resistance meter will be used in the laboratory experiment to collect measured value. In this research, we choose to use the Arduino board to process the operation and the voltage dividing principle to find resistance value to be displayed.

2. Design and development of an electrical resistance meter

In this section, we present the design and development of the software that controls the electrical resistance meter, we design the structure of the program to command the microcomputer to process and control operations in 3 parts which are compiler directive, body, and comment line using C language. The design and installation of the hardware of the electrical resistance meter consists of the equipment which are Arduino UNO R3 board, 1 kΩ constant resistor, voltage divider circuit, SD card module, RTC module, and 16x2 (1602) LCD display module with i2c interface, figure 1 shows the circuit’s connection and internal structures of the electrical resistance meter and the complete electrical resistance meter as shown in figure 2.

3. The efficiency of electrical resistance meter

In this section, we find the efficiency of an electrical resistance meter which are the percentage difference, the suitability of the electrical resistance meter, and the students’ satisfaction of the electrical resistance meter.

3.1. Finding the percentage difference and the display result of the electrical resistance meter

To find the efficiency of the electrical resistance meter in term of percentage difference, we compare the measured values from the instrument with the measured value from the reliable standard measuring meter (Fluke 115 digital multimeter). Considering the parameters, equation to calculate the different percentage is as in equation (1).
Define that $e$ is the different percentage, $R_1$ is the electrical resistance value as measured by a standard meter (ohm) and $R_2$ is the electrical resistance value measured by the electrical resistance meter we built (ohm). We measure 24 electrical resistors 5 times each, use carbon film fixed % error 1%, the result is shown in table 1.

**Table 1. Percentage different of the electrical resistance meter**

| Resistive value 1% (Ω) | Electrical resistance value as measured by a standard meter (Ω) | Electrical resistance value measured by the meter we built (Ω) | Percentage difference (%) |
|------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------|
| 1                      | 1.12                                                          | 1.10                                                          | -1.79                     |
| 1.5                    | 1.72                                                          | 1.69                                                          | -1.74                     |
| 5                      | 5.50                                                          | 5.47                                                          | -0.55                     |
| 10                     | 10.28                                                         | 10.17                                                         | -1.07                     |
| 15                     | 15.22                                                         | 15.06                                                         | -1.05                     |
| 22                     | 22.00                                                         | 22.02                                                         | +0.09                     |
| 47                     | 47.00                                                         | 47.23                                                         | +0.49                     |
| 100                    | 99.07                                                         | 101.00                                                        | +1.95                     |
| 300                    | 303.58                                                        | 301.20                                                        | -0.78                     |
| 500                    | 501.20                                                        | 504.57                                                        | +0.67                     |
| 700                    | 702.14                                                        | 706.30                                                        | +0.59                     |
| 900                    | 898.38                                                        | 901.29                                                        | +0.32                     |
| 1,100                  | 1,097.01                                                      | 1,102.49                                                      | +0.50                     |
| 1,300                  | 1,295.00                                                      | 1,301.25                                                      | +0.48                     |
| 1,500                  | 1,485.00                                                      | 1,510.37                                                      | +1.71                     |
| 1,700                  | 1,683.00                                                      | 1,715.42                                                      | +1.93                     |
| 1,900                  | 1,885.00                                                      | 1,918.64                                                      | +1.78                     |
| 2,000                  | 1,997.75                                                      | 2,004.80                                                      | +0.35                     |
| 3,000                  | 2,998.55                                                      | 3,001.22                                                      | +0.09                     |
| 100k                   | 99.94k                                                        | 100.15k                                                       | +0.21                     |
| 300k                   | 301.66k                                                       | 300.33k                                                       | -0.44                     |
| 560k                   | 566.64k                                                       | 561.01k                                                       | -0.99                     |
| 1M                     | 1.02M                                                         | 1.01M                                                         | -0.98                     |
| 2M                     | 2.03M                                                         | 2.01M                                                         | -0.99                     |

Note: the information was saved at 25 degree Celsius ±2 degree Celsius

From table 1, it is found that the percentage difference of the resistance is in the range between -1.79 and +1.95, which can be used to measure the electrical resistance effectively.
Figure 3. A .CSV file derived from data saving on the SD card by opening in Microsoft Excel, measuring resistance 500 Ω.

Figure 3 is the value of the data recorded in the SD card module, which is set to display as the resistance, date, and time obtained from the process of the program. The system will automatically generate a .CSV file and can be open using Microsoft Excel. For this experiment, the researcher wrote instructions for the Arduino board to read the resistance in every 5 seconds, which a method of storing this data on the SD card is an advantage to studying the behavior of the resistance change each time for measurement, so that we will be able to use the data to create graphs to see the relationship or to analyze the data in the correct statistical data [7].

3.2. Finding the suitability of the electrical resistance meter

To find the suitability of the electrical resistance meter, we invited 3 experts to evaluate the electrical resistance meter by the questionnaires that we created, the evaluation result as shown in table 2.

Table 2. The evaluation of experts’ opinions of the suitability of electrical resistance meter

| Topics                                      | x    | S.D. | Interpretation |
|---------------------------------------------|------|------|----------------|
| Appropriateness of positioning of the meter | 4.00 | 0.00 | High           |
| Appropriateness font size of the display    | 3.67 | 0.58 | High           |
| Suitability of shape and size               | 3.67 | 0.58 | High           |
| The strength of the meter                   | 4.33 | 0.58 | High           |
| Suitability of the design                   | 3.33 | 0.58 | Moderate       |
| Overall image of the meter                  | 4.00 | 0.00 | High           |
| Average                                     | 3.83 | 0.39 | High           |
| Ease of use                                 | 4.33 | 0.58 | High           |
| Ease of use settings                        | 4.33 | 0.58 | High           |
| Ease of circuit connection                  | 3.67 | 0.58 | High           |
| Accuracy of measurement values              | 4.67 | 0.58 | High           |
| Ease of movement                            | 3.67 | 0.58 | High           |
| Overall function                            | 4.00 | 0.00 | High           |
| Average                                     | 4.11 | 0.48 | High           |
| Ordering the content appropriately          | 4.00 | 1.00 | High           |
| Suitability illustration                    | 4.00 | 0.00 | High           |
| Suitability for user level                  | 4.33 | 0.58 | High           |
| Ease at reading and understanding           | 3.67 | 0.58 | High           |
| The manual has complete details of use      | 3.67 | 0.58 | High           |
| Average                                     | 3.93 | 0.55 | High           |
| Total average                               | 3.96 | 0.47 | High           |
3.3. Finding the students’ satisfaction

To find the students’ satisfaction, after the students use the electrical resistance meter in the physics laboratory subject, the satisfaction questionnaires of electrical resistance meter will be given to the students as the satisfaction evaluation results as shown in table 3.

| Topic                                           | \( \bar{x} \) | S.D. | Interpretation |
|-------------------------------------------------|---------------|------|----------------|
| Measuring tool are easy to store                 | 3.82          | 0.72 | High           |
| Materials used are at low cost                   | 4.11          | 0.79 | High           |
| The structure is strong                          | 4.04          | 0.84 | High           |
| Equipment parts are easy to find spare parts     | 4.11          | 0.88 | High           |
| Equipment parts can be easily repaired and easily replaced | 4.07          | 0.81 | High           |
| Average                                         | 4.03          | 0.81 | High           |
| Can be easily moved                              | 4.04          | 0.84 | High           |
| Can be easily set up for used                    | 4.07          | 0.81 | High           |
| Convenient to used                               | 3.86          | 0.80 | High           |
| Able to be read values correctly                | 4.14          | 0.76 | High           |
| Ease of use                                     | 4.11          | 0.79 | High           |
| Average                                         | 4.04          | 0.80 | High           |
| Easy to be read and understood                   | 3.82          | 0.77 | High           |
| The instruction manual order is suitable         | 4.18          | 0.77 | High           |
| Clear illustrations                              | 4.11          | 0.79 | High           |
| Cover all content                               | 3.96          | 0.74 | High           |
| Suitable font size                              | 3.68          | 0.72 | High           |
| Average                                         | 3.95          | 0.76 | High           |
| Total Average                                    | 4.01          | 0.79 | High           |

4. Conclusion

In conclusion, the design and development of the electrical resistance meter for using in physics laboratory for engineers has high accuracy with percentage different not more than 2 percent, showing that this measuring tool is practical and efficient. It will read the resistance as the error percentage and display the result on the LCD screen and save the data on the SD card. The evaluation by the experts has an average score of 3.96, which is at high level and the satisfaction evaluation has an average of 4.01 which is also at high level.

We also found that the students can create their own measuring tool for physics laboratory subject by themselves from the Arduino board, using their built-in measuring instruments to measure low (mΩ) and high (MΩ) resistances. The researchers had explained the work principle of the program and the voltage divider to the students before measuring resistance value. The appropriate reference resistance value \( R_{REF} \) must be calculated for various level of resistance measurements and corrected the resistance values in the program code for the most accurate results. The result shows that the students are interested in the operation of the program and the operation of the Arduino board in order to find answers. Therefore, they can create their own resistance measuring tools and be able to apply Arduino boards to measure electrical quantities or values related to physics [8]. This tool can be used to measure electrical resistance from voltage divider circuits. Moreover, the use of Arduino board can be applied to measure electrical resistance from force dividers or electric pressure and temperature sensor [9]. Currently, the Arduino board is further applied in other physics subjects in order to study the rules and formulas, as well as to create the tool to measure various types of experiments. Also Arduino board is very useful for physics experiments due to its low price and ability to connect with different sensors type efficiently for implementing Arduino board in teaching to make the students participate in their
study, creating systematic and creative thinking skills that can be applied for them to create a piece of work. It also makes the students be enthusiastic and cooperative in the experiment [10-12]. This modern technology increases the students’ interest. Using the Arduino board in physics experiments on various topics enables most of the students to provide comments that they are interested in the use of this tool in the experiments and the experiments can be done more easily with this tool [13-14].

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