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Inquiry Teaching Design of the Ohmmeter Modification Simulation Experiment

Suye Lü[a,*], Enzhong Tan[b], Shengtong Feng[c], Chunna Yu[d]

Beijing Institute of Petro Chemical Technology, Liberal Study College, Beijing, 102617, China
[a]lvsuye@bipt.edu.cn, [b]tanenzhong@bipt.edu.cn, [c]fengshengtong@bipt.edu.cn, [d]yuchunna@bipt.edu.cn
**Corresponding author: lvsuye@bipt.edu.cn*

Abstract: *The college physics experiment simulation system can be established by combining the information technology with the subject characteristics of College Physics Experiment. The system enriches the teaching mode and realizes the resource-sharing and digitization. However, it also brings some new problems, such as the neglect of deep understanding of experimental principles, a growing passive experimental design thinking, reckless and thoughtless experimental habits. Taking the Ohmmeter modification simulation experiment as an example, the paper discusses and actively practices the inquiry teaching of online college physics experiment. Through the inquiry process, it makes the students deeply realize that physical thought and physical knowledge are the foundation of physical experimental design.*

Keywords: *Simulation experiment, Ohmmeter modification, inquiry teaching*

1. Introduction

With the development of information technology, the education industry is undergoing great changes. All kinds of knowledge are being transmitted to students in a more intuitive, vivid and high effective way. In the laboratory construction and management of universities, a new phenomenon of "simulation laboratory teaching" has been emerged. Nowadays, multiple simulation experiment systems related to different subjects have been created, which enrich the teaching mode and greatly promote the teaching resource sharing and digitization [1-3]. The simulation experiment systems have the advantages of low cost, high security, high efficiency and supporting distance learning etc.

However, the idealized experimental process of simulation experiment sometimes makes students neglect the deep understanding of the experimental principle. Furthermore, because of the low cost of trial-and-error and the lack of intuitive understanding of fault problems in the simulation experiments, the reckless and thoughtless experimental habits may be formed easily. This is not conducive to cultivating students' scientific thinking, which is the core quality of physics. The scientific thinking is the ability to understand, analyze and finally solve problems. Under the teaching mode of simulation experiment, how to make students more consciously pay attention to the cognition of the basic experimental principles, and then actively form the experimental design thinking, and finally carry out the experimental operation with a clear idea is the most important teaching objective.

Inquiry teaching is a tentative method to solve the problem [4-5]. Simulation experiments based on human-computer interaction mode are short of interactive atmosphere, while inquiry teaching can enhance the interaction between teachers and students. For instance, it means teachers need to design more questions about the experiments when adopting simulation experiment teaching. Then, students can be guided to think by means of the designed questions. Thus, students' understanding and application of the theoretical knowledge can be deepened. Meanwhile, the blindness of students in the practical operation can be avoided to a certain extent.

Taking the Ohmmeter modification simulation experiment[1] as an example, the paper discusses and actively practices the inquiry teaching of online simulation physics experiment. Through inquiry teaching design, the actual simulation experiment content and theoretical teaching are organically integrated. Thus, students can realize that simulation experiments are only a way of experimental presentation, while physical thought and physical knowledge are the foundation of experimental design.

[1] *Multimeter design experiment, Electrical experiment, Keda Aorui virtual simulation experiment teaching cloud platform.*

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2. Inquiry question-posing and preliminary analysis

Inquiry question is the most important method for teachers, which is creative, openness, derivative and challenging. College physics experiment can be better reflected the teaching objective of quality education if students' practical and innovative ability are cultivated in experimental inquiry activities. As everyone knows, it is very important and necessary to ask "why" in the process of learning. Thus, students' ability to think and deal with problems can be cultivated truly. Therefore, it is more worthy of discussing that what physical knowledge can be used to change an Ammeter into an instrument for directly measuring resistance in this experiment.

Figure 1 shows the Microammeter used in the simulation experiment. It is crucial to guide students to notice the two sets of scale mark on the meter. One set is the Microammeter with even scale, which is familiar to students. The other set is Ohmmeter with uneven scale, which can be inferred from the unit (Ω). Then, "how to calibrate the set of uneven scale?" becomes a key question. In fact, it is the key question that guides students to think about "how to change the Microammeter into an Ohmmeter?"

Figure 1: The Microammeter used in the simulation experiment

Figures 2 is the circuit design schematics of an Ohmmeter, where E is the power supply, R_g is inner-resistance of the Microammeter, I_g is the full-scale current, R is the current limiting resistor, a and b are two terminals, and R_x is the resistance to be measured. In Figure 2(a), the two terminals a and b are directly connected with a wire, which means the measured resistance R_x =0. At this time, the current value in the circuit is maximum. It is set to be I_g which can be achieved by adjusting the variable resistance R. According to the Ohm Law, it is

$$I_g = \frac{E}{R_g + R} \tag{1}$$

where, R_g+R is the total inner-resistance of the modified Ohmmeter which is a constant. Note here: although R mentioned above is adjustable current limiting resistance, it has been fixed after the zeroing of the Ohmmeter. When short-circuited, the Microammeter can be adjusted to the full-scale by changing R. Therefore,

$$R = \frac{E}{I_g} - R_g \tag{2}$$

As shown in Figure 2(b), the two terminals a and b are disconnected, which means the measured resistance $R_x = \infty$. At this time, current indication of the Microammeter is zero.

Figure 2(c) shows the general situation, in which the two terminals a and b are connected with an arbitrary resistance R_x. Here, the relationship between the current I and the measured resistance R_x is

$$I = \frac{E}{R_g + R + R_x} \tag{3}$$

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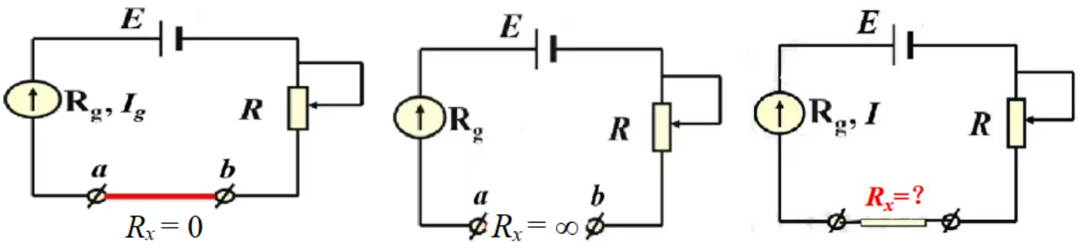

(a) (b) (c)

Figure 2: Calibration of zero scale mark (a), ∞ scale mark (b), and any scale mark (c) in Ohmmeter modification experiment

From equation (3), it can be derived that

$$R_x = \frac{E}{I} - \left(R_g + R\right) \tag{4}$$

where, R_g+R is the total inner-resistance of the modified Ohmmeter, which is a fixed value when the zero point of the Ohmmeter has been calibrated. E is the power supply.

It can be analyzed from formula (3) that when R_x changes, the corresponding current I can be calculated. That is to say, there is a one-to-one correspondence between R_x and I, as shown in formula (3) or (4). With the relationship, R_x can be calibrated on the dial of the Microammeter and then can be read directly. In fact, a physical thought has been applied here that one physical quantity can be used to represent another indirectly.

This is a principle exploration process based on the inquiry question-posing, which makes students recognize that the scale of Ohmmeter is reverse relative to that of the Microammeter. Moreover, it can be analyzed that the scale of the Ohmmeter is demarcated according to the one-to-one correspondence between R_x and I. Obviously, there is no proportional relationship between I and R_x. Therefore, the scale of Ohmmeter is uneven.

3. Modification design of the Ohmmeter in the simulation experiment

Now, we will further explore how to calibrate the uneven ohmmeter scale shown in Figure 1. The experimental instruments used in the simulation experiment are as follows: Microammeter, resistance box, power supply (1.5V), the test pens, six gear multi-position selective switch, signal box to be tested (see Figure 3).

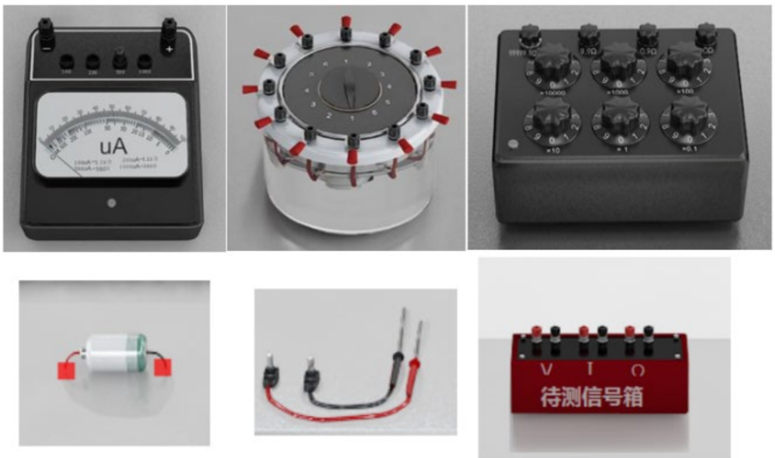

Figure 3: Experimental instruments used in the simulation experiment

Figure 4 is the circuit diagram of the Ohmmeter modification design in the simulation experiment. The modification requirement has been described in the simulation experiment, which is modifying the Microammeter with an inner-resistance R_g=560Ω and a full-scale current I_g =500μA into an Ohmmeter. It is required that the 100Ω scale of the modified Ohmmeter exactly corresponds to the 150μA scale of

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the Microammeter.

The Ohmmeter needs to be zeroed and calibrated. First of all, the zero point of the Microammeter must be corrected. That is, the pointer should point to the zero scale line at the left end of the Microammeter by conducting mechanical zero adjustment. Then, the zero point of the Ohmmeter should be calibrated. The circuit diagram in this case is shown as Figure 5. At this time, the red test pen and the black of the Ohmmeter are short circuited. By adjusting the resistance R_1, the full-scale current I_g passes through the Microammeter. Thus, zero-scale calibration of the Ohmmeter is completed.

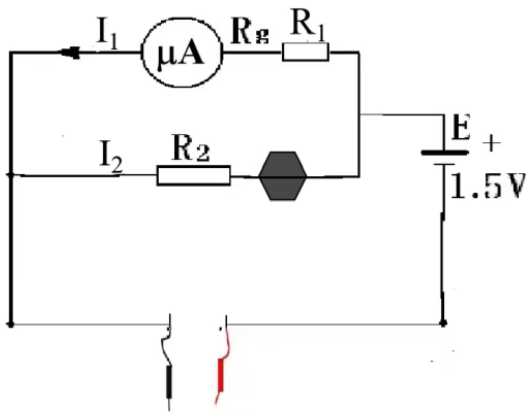

Figure 4: Ohmmeter modification design plan

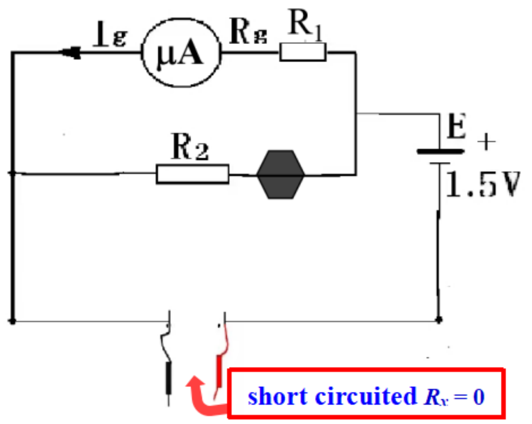

Figure 5: Zero-scale calibration of the Ohmmeter

In this case, E = 1.5V, I_g = 500μA, R_g = 560Ω. With the Ohm Law, it can be deduced that

$$I_g = \frac{E}{R_g + R_1} \tag{5}$$

where, R_1 is the zeroing resistance whose value is 2440Ω calculated by substituting the three known values into formula (5). At this time, the pointer points to the full-scale mark of the Microammeter, which is also the position of the zero-scale line of the Ohmmeter.

Finally, the Ohmmeter should be calibrated. It has been given that the 100Ω scale mark of the modified Ohmmeter exactly corresponds to the 150μA scale mark of the Microammeter. The test pens are connected to the third resistance box whose value is adjusted to be R_x = 100Ω, as shown in Figure 6. Then, according to the modification requirement, R_2 should be adjusted to make the pointer just points to the scale mark 30 of the Microammeter. The position corresponds to the current 150μA. During the above adjustment, R_1 = 2440Ω remains unchanged. Here, E = 1.5V, R_g = 560Ω, R_x = 100Ω, R_1 = 2440Ω, I_1 = 150μA. According to the Ohm Law, the two equations can be obtained as follows:

$$E = (I_1 + I_2)R_x + I_1(R_1 + R_g) \tag{6}$$

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$$I_1(R_1 + R_g) = I_2 R_2 \tag{7}$$

Here, R_2 is calculated to be 43.48Ω, which is the calibration resistance. When the calibration resistance R_2 equals 43.48Ω, the pointer of the Microammeter points to the 30 scale line (corresponding current I_1 = 150μA). Thus, the calibration of the Ohmmeter is completed.

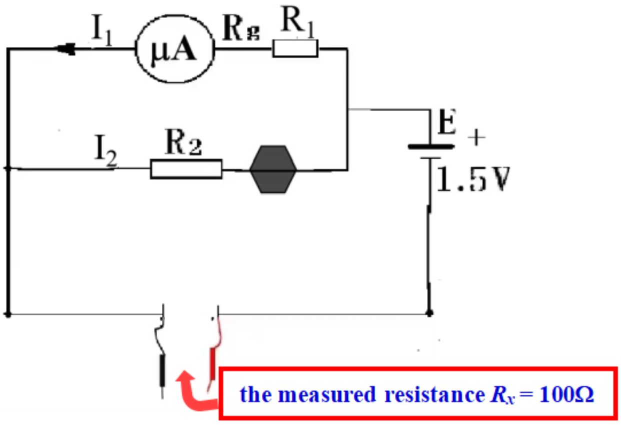

Figure 6: Calibration of the Ohmmeter

When R_1 = 2440Ω and R_2 = 43.48Ω are determined, any other scale mark of the Ohmmeter can be calibrated. In order to better understand this point, the relationship between the measured resistance R_x and the current I_1 will be studied through theoretical calculation. According to the data listed in Table 1, Figure 7 is obtained.

Table 1: The relationship between the measured resistance R_x and the current I_1

R_x/Ω	5	10	15	20	30	50	100	200	500	4000
I_1/μA	447.8	405.4	370.4	340.9	294.1	230.8	150.0	88.2	39.5	5.3
scale line	89.6	81.1	74.1	68.2	58.8	46.2	30.0	17.6	7.9	1.1

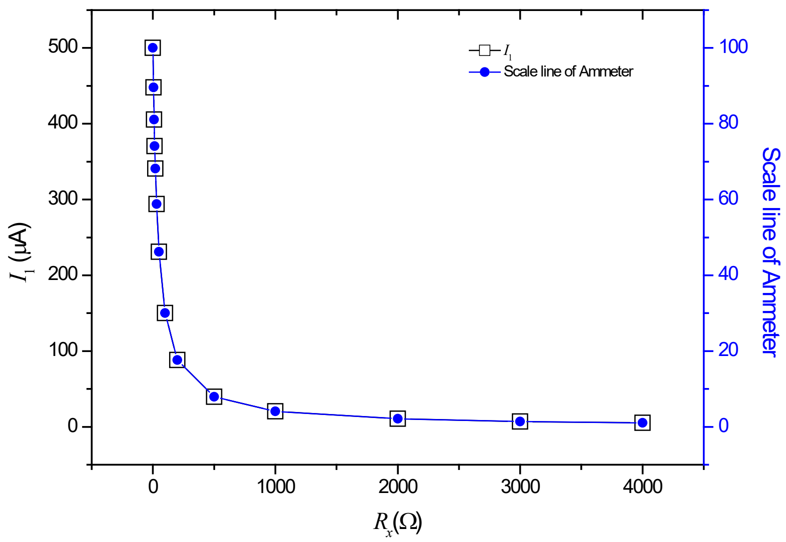

Figure 7: I_1 and the scale line of the Microammeter varied with R_x

Several specified scales of the Ohmmeter in the simulation experiment can be calibrated with the data in Table 1 or Figure 7. In fact, this is also a general experimental research method to study the one-to-one correspondence between R_x and I_1. Furthermore, the corresponding theoretical relationship can be obtained with the Ohm Law, which is as follows:

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$$I_1 = \frac{E}{R_x + \frac{(R_1 + R_g)R_x}{R_2} + (R_1 + R_g)} = \frac{1.5}{R_x + \frac{3000R_x}{43.48} + 3000} \quad (8)$$

Formula (8) is the analytic relation between I_1 and R_x, as shown in Figure 8. According to formula (8), any one-to-one correspondence (R_x, I_1) can be obtained. Therefore, the set of uneven scale in Figure 1 can be calibrated. Thus, the key question of “how to calibrate the set of uneven scale?” has been answered.

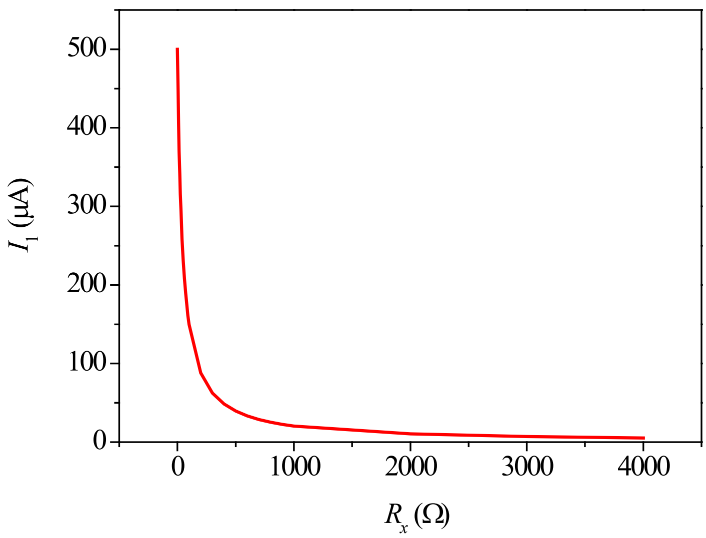

Figure 8: Analytical relationship between R_x and I_1

With the Ohmmeter modification completed, it can be used to measure the unknown resistance of the signal box, as shown in Figure 9. According to the calibrated scale mark of the Ohmmeter, the unknown resistance value can be read directly.

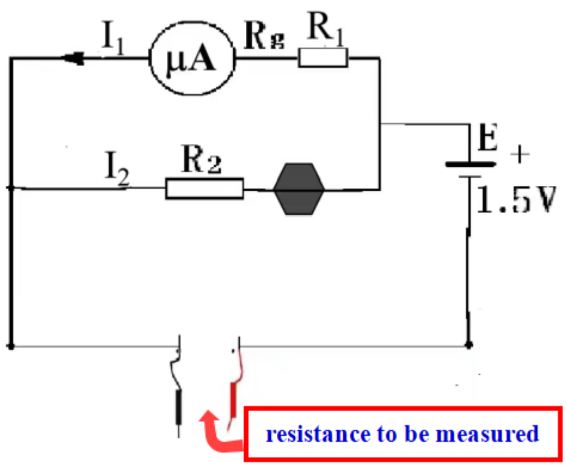

Figure 9: Resistance to be measured with the modified Ohmmeter

4. Conclusions

Taking the Ohmmeter modification simulation experiment as an example, the paper focuses on the problem of “how to calibrate the scale mark of the Ohmmeter modified from the Microammeter?” The

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problem guides students to explore the uneven Ohmmeter scale mark which has already appeared in the simulation experiment. In fact, the calibration of the Ohmmeter scale is the most critical theoretical understanding and experimental operation link in the process of this offline experiment. However, it is very easy for students to ignore the calibration process of the Ohmmeter scale in the simulation experiment system. Instead, with the existed Ohmmeter scale, students usually emphasize on the operation links such as Ohmmeter zeroing, calibration and measurement. Thus, the teaching objective of deeply understanding the physical theorem by the experiment cannot be achieved. Here, the operation parts of the offline and the online experiment are well integrated, and inquiry teaching method has been used to make students focus on understanding how to calibrate the scale of the Ohmmeter. In the teaching process, teachers should emphasize on the two experimental links of the Ohmmeter zero adjustment and its calibration, which are helpful for students to deeply understand the one-to-one correspondence between the measured resistance and the current passed through the Microammeter. In terms of some examples, students can understand the method of using offline experiment to study the relationship between the current and resistance to be measured. According to the theoretical derivation, the analytical relationship between the two physical quantities is obtained, with which any scale line of the Ohmmeter panel can be calibrated. Finally, it is realized that students' profound understanding of "physical knowledge and physical thought are the foundation of physical experimental design".

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