Score

Physical Experiment Ⅱ

Physics Lab Report 12

Experiment Title:	The Wheatstone Bridge and the Prototype of Electric Balance
Student Number:	2017200602011
Chinese Name:	张立澄
Teaching Assistant:	Hao Wen
Instructor:	Jing Wu
Lab Date:	2018.11.8

Score

Abstract (About 100 words, 10 points)

This purpose of this experiment is to understand the principles of the Wheatstone Bridge and the electric balance. During this experiment, we measure the outputs of quarter bridge circuit and half bridge circuit. After that, we analyzed the data and drew graphs to find the approximately positive correlation relationship between the output voltage and the input voltage. Besides, we figured out the sensitivity of the prototype electric balance by mathematical analysis, which means it is easy to find the mass of measured objects by measuring the average U with the equation $m = \frac{U}{S}$, and we also found that the sensitivity of half bridge circuits is twice as the quarter bridge circuits.

Score

Calculations and Results (Calculations, data tables and figures; 15 points)

Calculations

(1) Use the results in Data table 3.12-1 and 3.12-2 to calculate the sensitivity of the quarter and half bridge circuits, respectively.

$$S = \frac{U}{\Delta R} = \frac{\frac{0.012}{0.2} + \frac{0.028}{0.4} + \frac{0.045}{0.6} + \frac{0.065}{0.8} + \frac{0.080}{1.0} + \frac{0.085}{1.2}}{6} = 0.072\text{V/kg}$$

$$S = \frac{U}{\Delta R} = \frac{\frac{0.025}{0.2} + \frac{0.055}{0.4} + \frac{0.085}{0.6} + \frac{0.125}{0.8} + \frac{0.165}{1.0} + \frac{0.170}{1.2}}{6} = 0.131\text{V/kg}$$

(2) Based on the above calculations, determine the relationship between the two sensitivities.

The sensitivity of the half bridge circuits is about twice as the quarter bridge circuits.

(3) The sensitivity of the prototype of an electric balance S is defined as the ratio of change in difference voltage (ΔU) to the change in mass (Δm).

$$\text{S} = \frac{\Delta U}{\Delta m} \quad \text{(V/kg)}$$

Use the results in Data Table 3.12-3 to calculate the sensitivity of your prototype by the method of least-square fitting.

$$\overline{mU} = \frac{1\times0.050 + 2\times0.130 + 3\times0.200 + 4\times0.285 + 5\times0.300 + 6\times0.365 + 7\times0.440 + 8\times0.515 + 9\times0.585}{9}$$

$$= 2.022$$

$$\overline{U} = \frac{0.050 + 0.130 + 0.200 + 0.285 + 0.300 + 0.365 + 0.440 + 0.515 + 0.585}{9} = 0.318$$

$$\overline{m} = \frac{1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9}{9} = 5$$

$$\overline{m^2} = \frac{1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9^2}{9} = 31.667$$

$$\text{a} = \frac{\overline{m} \cdot \overline{mU} - \overline{U} \cdot \overline{m^2}}{\overline{m}^2 - \overline{m^2}} = \frac{-9.960}{-6.667} = 1.49$$

$$\text{b} = \frac{\overline{m} \cdot \overline{U} - \overline{mU}}{\overline{m}^2 - \overline{m^2}} = \frac{-0.432}{-6.667} = 0.065$$

U=a+bm=1.49+0.065m

Thus, S=0.065 V/kg.

(4) After finding the sensitivity of the prototype, use Equation (3.12-16) to calculate the mass of the measured objects in Data Table 3.12-4. Show the details of calculation for the first object.

$$m = \frac{U}{S} = \frac{0.08V}{0.065\text{V/kg}} = 1.23kg$$

Data Tables

DATA TABLE 5-1 (*purpose*: to measure the output of quarter bridge circuit)

R_3 (kΩ)	10.2000	10.4000	10.6000	10.8000	11.0000	11.2000
U_{AB} (V)	0.025	0.048	0.075	0.095	0.120	0.152

DATA TABLE 5-2 (*purpose*: to measure the output of half bridge circuit)

R_3 (kΩ)	10.2000	10.4000	10.6000	10.8000	11.0000	11.2000
R_4 (kΩ)	9.8000	9.6000	9.4000	9.2000	9.0000	8.8000
U_{AB} (V)	0.025	0.055	0.085	0.125	0.165	0.170

DATA TABLE 5-3 (*purpose*: to measure the sensitivity of the prototype of electric balance)

Weight (kg)	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000
U_+ (V) (Loading)	0.08	0.17	0.25	0.34	0.31	0.37	0.44	0.52	0.59
U_- (V) (Unloading)	0.02	0.09	0.15	0.23	0.29	0.36	0.44	0.51	0.58
Averaged, $\overline{U}$ (V)	0.050	0.130	0.200	0.285	0.300	0.365	0.440	0.515	0.585

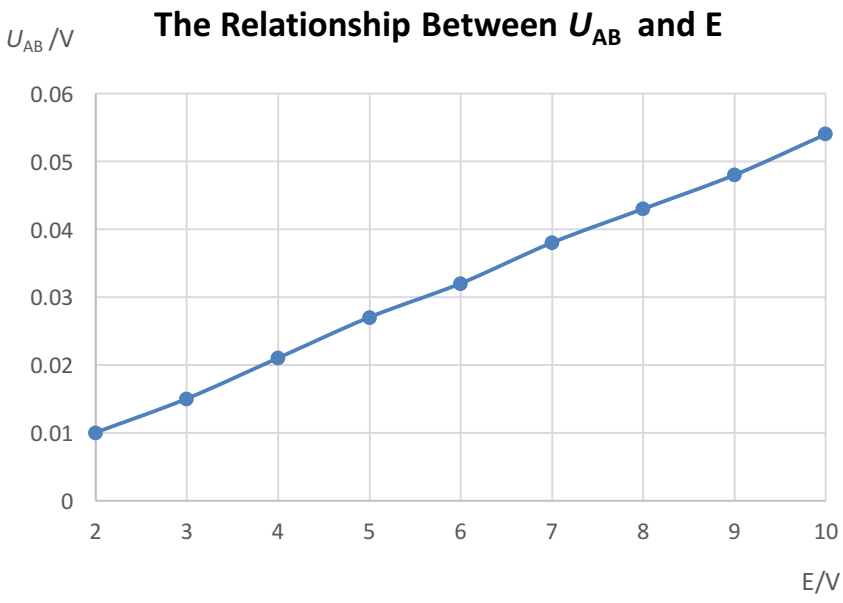
DATA TABLE 5-4 (*purpose*: to measure the mass of three random objects)

Trial	Object 1 (V)	Object 2 (V)	Object 3 (V)
1	0.08	0.01	0.09
2	0.09	0.02	0.07
3	0.07	0.02	0.09
Averaged, $\overline{U}$	0.08	0.017	0.083
Mass, m (kg)	1.23	0.26	1.28

DATA TABLE 5-5 (*purpose*: to probe the relationship between the input voltage and the output)

Input voltage, E (V)	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Output, U_{AB} (V)	0.010	0.015	0.021	0.027	0.032	0.038	0.043	0.048	0.054

Graphing



As we can see from the graph, the relationship between U_{AB} and E can be described as an approximately positive correlation.

Score

Conclusions (About 100 words, 5 points)

This experiment helped us understand the principles of the Wheatstone Bridge and the electric balance, probe the positive correlation relationship between the output voltage and the input voltage, and find the sensitivity of prototype. The real experiment situation is not the same as the theory completely, many factors can cause problems which are beyond our thoughts, including the connecting method of circuit and the error of equipment. What we can do is just choose and use the most proper method to reduce the errors, for example, in this experiment, by using the method of least-squares fitting to analyze the data and measure both the loading and the unloading voltages to obtain the average values.

Score

Answers to Questions (10 points)

1. Because the formula for four active resistances is $S = \frac{U}{R}$ which means it is easier to calculate and analyze, and using active resistors is helpful to find a positive value of S.

2. The relationship between the output voltage and the input voltage can be described as an approximately positive correlation. The input voltage can not be increased without limits in order to increase the output, because the resistors have rated voltage, which means if the input voltage reach a considerably large value and then the current would be large and cause the circuit break down.

Appendix

(Scanned data sheets)

3.12.5 Experimental Data

Data Table 3.12-1 ***Purpose*: To measure the output of quarter bridge circuit**

R_3 / kΩ	10.2000	10.4000	10.6000	10.8000	11.000	11.2000
U_{AB}/V	0.012	0.028	0.045	0.065	0.080	0.085

Data Table 3.12-2 ***Purpose*: To measure the output of half bridge circuit**

R_3/kΩ	10.2000	10.4000	10.6000	10.8000	11.0000	11.2000
R_4/kΩ	9.8000	9.6000	9.4000	9.2000	9.0000	8.8000
U_{AB}/V	0.025	0.055	0.085	0.125	0.165	0.170

Data Table 3.12-3 ***Purpose*: To measure the sensitivity of the prototype electric balance**

Weight/kg	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000
U_+/V(Loading)	0.08	0.17	0.25	0.34	0.31	0.37	0.44	0.52	0.59	0.66
U_-/V(Unloading)	0.02	0.09	0.15	0.23	0.29	0.36	0.44	0.51	0.58	0.66
Average, $\bar{U}$ /V	0.050	0.130	0.200	0.285	0.300	0.365	0.440	0.515	0.585	0.660

Data Table 3.12-4 ***Purpose*: To measure the mass of three random objects**

Trial	Object 1 (Name:)/V	Object 2 (Name:)/V	Object 3 (Name:)/V
1	0.08	0.01	0.07
2	0.09	0.02	0.09
3	0.07	0.02	0.09
Average, $\bar{U}$	0.08	0.017	0.083
Mass, *m*/kg	1.23	0.26	1.28

Data Table 3.12-5 ***Purpose*: To probe the relationship between the input voltage and the output**

Input voltage, *E*/V	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Output voltage, U_{AB} /V	0.010	0.015	0.021	0.027	0.032	0.038	0.043	0.048	0.054

Student's name and number: 张三然 20172006020111 Instructor's initial: Jing Wu