电子科技大学
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Physics Lab Report

Experiment Title: The Wheatstone Bridge and the Prototype of Electric Balance

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Date Performed: 26th November

Score

Abstract (About 100 words, 3 points)

In this experiment, we should know something about the Wheatstone Bridge and the Prototype of Electric Balance. The bridge is a kind of circuit which could help us to learn the balance of the electric circuit.

And according to the hand book about the physics experiment, I finish this experiment and record the data, and these procedures really help me to know loads of knowledge on the electric balance.

These results tell me that there is a condition called electric balance and the experiment named the Wheatstone Bridge can help us to explore this property. At the same time, I know that when the electrical circuit is balanced, there is no current in the circuit.

All in all, this experiment helps me to understand deeper in the electric circuit and the electric balance and the electromotive force as well as the how we can sue this property to do something.

Score

Introduction (3 points)

A Wheatstone bridge is an electrical circuit design dating back to 1800's. It was invented by a British scientist Samuel Hunter Christie (1784-1865) and first described in 1833. It is named after its most famous user, Sir Charles Wheatstone, who did develop multiple uses for it. The purpose of this experiment is to understand a Wheatstone bridge circuit and its application in electric balance.

After performing this experiment and analyzing the data, we should able to:

- Understand the operating principles of the Wheatstone bridge.
- Understand the principle of an electric balance.

And the experiment procedure is really helpful for me to explore these properties and can help us to even understand deeper on the field of electric circuit.

Score

Experimental Procedure (State main steps in order of performance, 3 points)

Measure the difference voltage of quarter bridge circuit

1. Set up a circuit as shown in fig.3.12-7, where R_1 and R_2 are fixed resistors with resistance values of 1MΩ. R_3 and R_4 are two variable resistors of boxes.
2. Check your circuit again and turn on the power.
3. Tune the " adjustment knob to set E = 6.00 volts (see fig 3.12-7). Set the resistance values of the two variable resistors to $R_3 = R_4$ =10KΩ and the bridge is balanced and the difference voltage should be zero. However, in most cases, the difference voltage (the Wheatstone bridge output is not zero (think about the possible reasons). Tune the " bias " knob to set the difference voltage $U_{ab} = 0$.
4. Increase R_3 in an increment of 200Ω until it reaches $11.200K\Omega$. read the corresponding difference voltages registered on the voltmeter and enter them in Data Table 3.12-1. (We should be careful that all the difference voltages must have more than one significant figure. You can turn the “gain” knob to amplify the difference voltage for the first reading. However, don’t turn it any more in the subsequent measurement.)

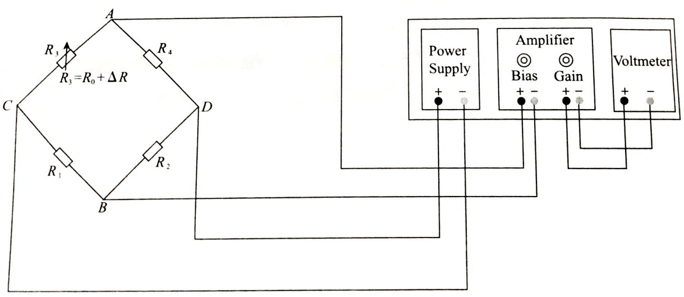


Fig. 3.12-7 Schematic diagram for the circuit connection of the resistors, power supply, amplifier, and voltmeter

Measure the difference voltage of the half bridge circuit.

1. Use the circuit in fig 3.12-7. Set $E = \mu_{CD} = 6.00\ volts$.
2. Set the resistance values of the two variable resistors to $R_3 = R_4 = 10K\Omega$ and the bridge is balanced. Tune the knob of " zero " to set the difference voltage $U_{AB} = 0$. Increase R_3 in an increment of 200Ω and decrease R_4 in an increment of 200Ω, until R_3 and R_4 reach $11.200K\Omega$ and $8.8000K\Omega$, respectively. Read the difference voltages registered on the voltmeter and enter them in data table 3.12-2. Don’ tune the “gain” knob in this step.

Determine the sensitivity of the prototype electric balance and measure the mass of objects.

There is a prototype electric balance available on the bench. it is made by the principles of strain gauge and Wheatstone full bridge. In this section, we will determine the sensitivity of the prototype by experiment and then we utilize this device to measure the mass of objects

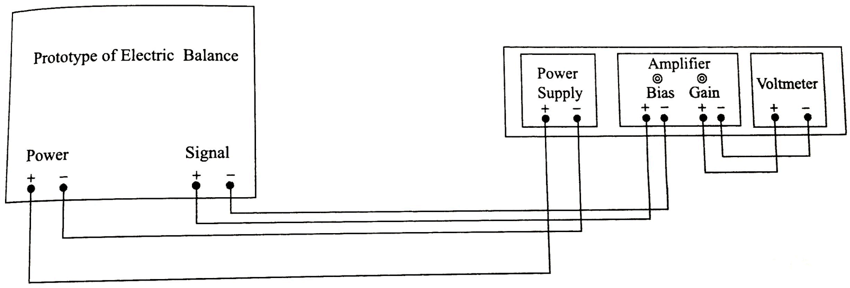


Fig. 3.12-8 Schematic diagram for the circuit connection of the prototype electric balance, the power supply, the amplifier, and the voltmeter

1. Set up the circuit for the prototype of electric balance, as shown in fig.3.12-8.
2. Turn on the power and let the prototype warm up for five minutes.
3. Set $E = 6.00\ volts$. Tune the " bias " knob to set the difference voltage to 0.
4. Add a weight per time on the table of the prototype. Read the voltage registered on the voltmeter after adding each weight record the voltages in Data table 3.12-3. (Be careful that all the voltages must have more than one significant figure. We can tune the "gain" knob to amplify the voltage for the first reading. However, don't tune it any more in the following measurements)
5. Unload one weight at a time and read the voltmeter at each step. Record the readings in data table 3.12-3.
6. Put one object such as a pencil box, or a cell phone on the table of the prototype. read the voltage and enter it in data table 3.12-4.
7. Take it off and put it on the table and then measure it again two more times record the voltages in data table 3.12-4.
8. Repeat steps 6 and 7 to measure two more objects. Record the output in data table 3.12-4.
9. Put one weight on the table of the prototype. tune the knob to set the source voltage to 2 volts. Read the output and enter it in data table 3.12-5. You must ensure that all the voltages have more than one digit.
10. Increase the source voltage by 1 volt per time until it reaches 1 0 volts. Read the difference voltage after each increase record the voltages in data Table 3.12-5.

Score

Results (Data tables and figures, 2 points)

1. 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)	0.006	0.007	0.008	0.010	0.011	0.012

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)	0.012	0.014	0.017	0.020	0.022	0.024

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	10.000
U_+ (V) (Loading)	0.019	0.023	0.028	0.033	0.038	0.043	0.048	0.053	0.058	0.063
U_- (V) (Unloading)	0.018	0.023	0.028	0.033	0.038	0.042	0.047	0.053	0.058	0.063
Averaged, $\overline{U}$ (V)	0.019	0.023	0.028	0.033	0.038	0.043	0.048	0.053	0.058	0.063

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

Trial	Object 1 (Name: label) (V)	Object 2 (Name: cup) (V)	Object 3 (Name: pencil case) (V)
1	0.017	0.018	0.017
2	0.015	0.017	0.015
3	0.013	0.019	0.016
Averaged, $\overline{U}$	0.015	0.018	0.016
Mass, m (kg)	0.13	0.94	0.53

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)	0.008	0.011	0.013	0.015	0.018	0.021	0.023	0.025	0.029

Score

Discussion (More than 150 words, 5 points)

According to the procedure in the book, we do the experiment and we also double check my result according to the fundamental knowledge I have learnt from high school, physics and CAD. These knowledges include how to measure the resistance, how to calculate the electromotive force the Kirchhoff's current law as well as Kirchhoff's voltage law which could help me to measure the data successfully. Also, we also learn something about the apparatus in the experiment and how to operate them. When we are recording our data, we also wait the voltage shown on the apparatus to keep static and then record it, as the weight resistant might be not so accurate when the shape change isn't fully finished and the resistant may not change completely. So, this could help me to get more accurate data. At the same time, we also measure the voltage when we add some weight on the pressure related resistant and continuing record when we remove the weight from it. This is a good method to make our data accurate as it can reduce the error of this apparatus.

Score

Conclusions (About 50 words, 2 points)

The calculation steps (Including bringing in data) are in the appendix

Calculations

(1) From the results in Data table 5-1 and 5-2, conclude the relationship between the sensitivity of the bridge and the resistance change for the quarter and half bridge circuits, respectively.

- $S_{U-Q} = 1.5\times10^{-4}$
- $S_{U-H} = 3\times10^{-4}$

(2) From the results in Data table 5-1 and 5-2, conclude the relationship between the two sensitivities of the quarter and half bridge circuits.

- **Formulas for one active resistant:** $S_{U-Q} = \frac{U_0}{4R_0}$
- **Formulas for two active resistances:** $S_{U-H} = \frac{U_0}{2R_0}$

$$\text{So } S_{U-H} = 2S_{U-Q}$$

(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).

$$S = \frac{\Delta U}{\Delta m} \quad \text{(in V/kg)} \quad (5\text{-}16)$$

$$\bar{m} = 5.5kg$$

Use the results in Data Table 5-3 to calculate the sensitivity of your prototype by the method of least-square fitting.

$$\bar{u} = 0.0406\text{V}$$

$$\overline{mu} = 0.2641$$

$$\overline{m^2} = 38.5$$

$$\bar{m}^2 = 30.25$$

$$a = \frac{\bar{m} \cdot \overline{mu} - \bar{u} \cdot \overline{m^2}}{\bar{m}^2 - \overline{m^2}} = 0.0134$$

$$b = \frac{\bar{m} \cdot \bar{u} - \overline{mu}}{\bar{m}^2 - \overline{m^2}} = 0.0049$$

U=0.0134+0.0049m

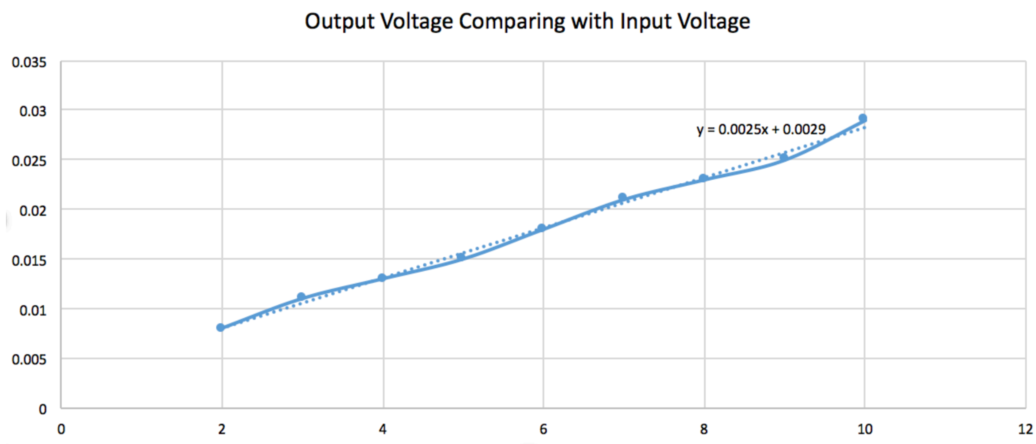
$$S = 0.0049$$

After finding the sensitivity of the prototype, use Equation (5-16) to calculate the mass of the measured objects in Data Table 5-4. Show the details of calculation for the first object。

$$U = 0.0134 + Sm$$

$$m = \frac{U - 0.0134}{S} = \frac{0.015 - 0.0134}{0.0049} \approx 0.32kg$$

The calculation steps (Including bringing in data) are in the appendix



Score

References (1 points)

Some parts I write on this prelab which is reference from Wikipedia and Baidu.

Some parts of my report was got from the book (Introductory physics experiments for undergraduates, Haofu)

Some of the words and formulas are from materials on BB9. Calculations were down by my partner Yue and me Musk.

Score

Answers to Questions (6 points)

1. **Normally, four active resistors are used in the wheatstone bridge circuit. Why?**

   As we can know from the handbook of the physics experiment, we can get:

   Formulas for one active resistant: $\mathbf{S_{u-max} = \frac{U_0}{4R_0}}$

   Formulas for two active resistances: $\mathbf{S_u = \frac{U_0}{2R_0}}$

   Formulas for four active resistances: $\mathbf{S_u = \frac{U_0}{R_0}}$

   From these formulas, we can derive that the four active resistances can help us to get the highest sensitive S, and this is good for our experiment to let us know the change.

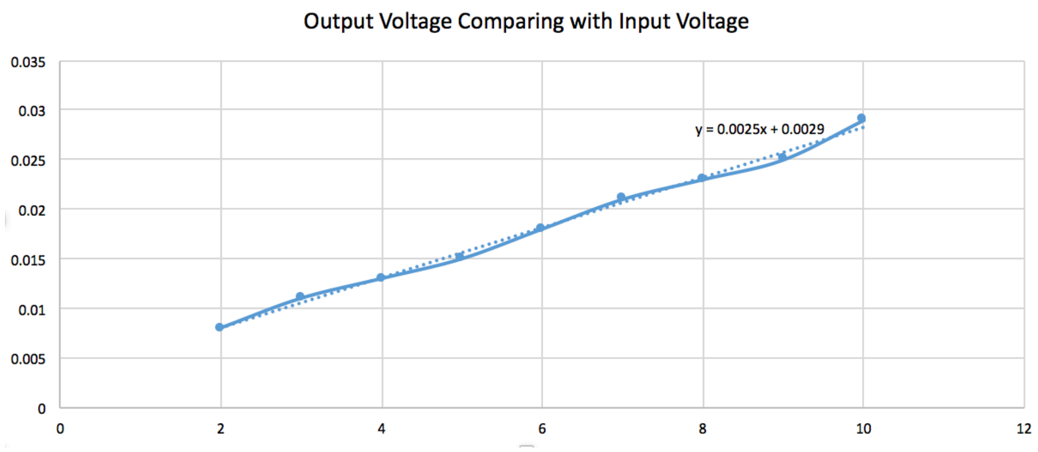
2. **For the prototype of an electric balance, what's the relationship between the output voltage and the input voltage? Can the input voltage be increased without limits in order to increase the output? Why?**

   From the graph which I plot before, we can know that:

   $$\boldsymbol{V_{output} = 0.0025V_{input} + 0.0029}$$

   According to this, we ca see that this is a linear regression model and normally if we increase the input voltage and the output voltage would increase continuously.

However, we can know that if we increase the input voltage to a considerably large value, we can see that the current would be large and the resistant or the wire may could not support such huge current and Circuit may failure because of this.



Appendices

Score

(Calculations, 15 points)

Calculated by me and my partner.

Ex. 3.12

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(1) (a) Quarter ~~brig~~ bridge circuit

$\cancel{k=\frac{R_1}{R_2}=}$ $\because R_1=R_2=1M\Omega$ $R_0=R_4=10k\Omega$

$\therefore k=\frac{R_1}{R_2}=\frac{R_0}{R_4}=1 \Rightarrow S_{uQ}=\frac{kU_0}{(1+k)^2R_0}=\frac{6}{4\times10^4}=1.5\times10^{-4}$

(b) Half bridge circuit

$\because R_1=R_2=1M\Omega$ $R_0=R_4=10k\Omega$

$U_0=6V$

$\therefore S_{uH}=\frac{U_0}{2R_0}=\frac{6}{2\times10^4}=3\times10^{-4}$

(2) From (1)(a) and (1)(b)

Because the value of resistor R_1, R_2, R_0, R_4 are equal in the quarter bridge circuit and half bridge circuit

$\because S_{u\text{-}Q}=\frac{U_0}{4R_0}$ $S_{u\text{-}H}=\frac{U_0}{2R_0}$

$\therefore S_{u\text{-}H}=2S_{u\text{-}Q}$

(3) $\overline{m} = \frac{1}{10}(1+2+3+\cdots+10) = 5.5kg$

$\overline{u} = \frac{1}{10}(0.018+0.023+0.028+0.033+0.038+0.043+0.048+0.053+0.058+0.063)$

$= 0.0406V$

$\overline{m \cdot u} = \frac{1}{10}(1\times0.018+2\times0.023+3\times0.028+4\times0.033+5\times0.038+6\times0.043+7\times0.048+8\times0.053+9\times0.058+10\times0.063)$

$= 0.2641$

$\overline{m^2} = \frac{1}{10}(1^2+2^2+3^2+4^2+5^2+6^2+7^2+8^2+9^2+10^2) = 38.5$

$\overline{m}^2 = 30.25$

Assume $U = a+bm$, By the least-square method

$$a = \frac{\overline{m}\cdot\overline{mu} - \overline{U}\cdot\overline{m^2}}{\overline{m}^2 - \overline{m^2}} = \frac{5.5\times0.2641 - 0.0406\times38.5}{30.25-38.5} = 0.0134$$

$$b = \frac{\overline{m}\cdot\overline{U} - \overline{m\cdot u}}{\overline{m}^2 - \overline{m^2}} = \frac{5.5\times0.046 - 0.2641}{30.25-38.25} = 0.0049$$

$\Rightarrow U = 0.0134 + 0.0049m$

$\because S = \frac{\Delta U}{\Delta m} \quad \therefore S = b = 0.0049$

(4) Object 1 : Label

$$U = 0.0134 + Sm \Rightarrow m = \frac{U-0.0134}{S} = \frac{0.015-0.0134}{0.0049} \approx 0.32 kg$$

Calculations

(4) From the results in Data table 5-1 and 5-2, conclude the relationship between the sensitivity of the bridge and the resistance change for the quarter and half bridge circuits, respectively.

- $S_{U-Q} = 1.5\times10^{-4}$
- $S_{U-H} = 3\times10^{-4}$

(5) From the results in Data table 5-1 and 5-2, conclude the relationship between the two sensitivities of the quarter and half bridge circuits.

- **Formulas for one active resistant:** $\mathbf{S_{U-Q} = \frac{U_0}{4R_0}}$
- **Formulas for two active resistances:** $\mathbf{S_{U-H} = \frac{U_0}{2R_0}}$

$$\text{So } S_{U-H} = 2S_{U-Q}$$

(6) 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).

$$S = \frac{\Delta U}{\Delta m} \quad \text{(in V/kg)} \quad \text{(5-16)}$$

$$\bar{m} = 5.5kg$$

Use the results in Data Table 5-3 to calculate the sensitivity of your prototype by the method of least-square fitting.

$$\bar{u} = 0.0406\text{V}$$

$$\overline{mu} = 0.2641$$

$$\overline{m^2} = 38.5$$

$$\bar{m}^2 = 30.25$$

$$a = \frac{\bar{m}\cdot\overline{mu} - \bar{u}\cdot\overline{m^2}}{\bar{m}^2 - \overline{m^2}} = 0.0134$$

$$b = \frac{\bar{m}\cdot\bar{u} - \overline{mu}}{\bar{m}^2 - \overline{m^2}} = 0.0049$$

U=0.0134+0.0049m

$$S = 0.0049$$

After finding the sensitivity of the prototype, use Equation (5-16) to calculate the mass of the measured objects in Data Table 5-4. Show the details of calculation for the first object。

$$U = 0.0134 + Sm$$

$$m = \frac{U - 0.0134}{S} = \frac{0.015 - 0.0134}{0.0049} \approx 0.32kg$$

Calculated by me and my partner.

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	0.006	0.007	0.008	0.010	0.011	0.012

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	0.012	0.014	0.017	0.020	0.022	0.024

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)	0.018	0.023	0.028	0.033	0.038	0.043	0.048	0.053	0.058	0.063
U_-/V(Unloading)	0.018	0.023	0.028	0.033	0.037	0.042	0.047	0.053	0.058	0.063
Average, $\bar{U}$ /V	0.018	0.023	0.028	0.033	0.038	0.043	0.048	0.053	0.058	0.063

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

Trial	Object 1 (Name: Label)/V	Object 2 (Name: cup)/V	Object 3 (Name: pencil case)/V
1	0.017	0.018	0.017
2	0.015	0.017	0.015
3	0.013	0.018	0.016
Average, $\bar{U}$	0.015	0.018	0.016
Mass, m/kg	0.13	0.94	0.53

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	0.008	0.011	0.013	0.015	0.018	0.021	0.023	0.025	0.028

Student's name and number: [illegible] 2016200302027 Instructor's initial: Jing Wu