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直流平衡电桥测电阻

一、数据处理

1. 将平衡电桥测电阻的结果列表，计算灵敏度 S。

万用表粗测结果：$R_x = 29.10\Omega$

条件				直接量			间接量		
E/V	R_h $/\Omega$	R_1/Ω	R_2/Ω	R_0/Ω n	R_0'/Ω n'	Δn	$\Delta R_0/\Omega$	$R_x = \frac{R_1}{R_2}R_0$	$S = \frac{R_0\Delta n}{\Delta R_0}$
2.0	0	100	100	33.0 −3.9	32.9 4.0	7.9	0.1	32.9(R_{x3})	$\frac{7.9\times 33.0}{0.1} = 2607$
		100	1k	332.2 0	333.2 2.3	2.3	1.0	33.22(R_{x4})	$\frac{2.3\times 332.2}{1.0} = 764.06$
		1k(A)	1k(B)	33.9 0	32.9 1.3	1.3	1.0	33.9(R_{x1})	$\frac{1.3\times 33.9}{1.0} = 44.07$
		1k(B)	1k(A)	32.3 0	33.0 0.9	0.9	0.7	32.3(R_{x2})	$\frac{0.9\times 32.3}{0.7} = 41.53$
	3k	100	100	33.4 0	35.0 4.0	4.0	1.6	33.4(R_{x5})	$\frac{4.0\times 33.4}{1.6} = 83.5$
1.0	0	100	100	33.4 2.0	33.5 -2.0	4.0	0.1	33.4(R_{x6})	$\frac{4.0\times 33.4}{0.1} = 1336$

2. 计算交换桥臂测量法测得的电阻值及其不确定度。

$$R_x = \sqrt{R_{x1}R_{x2}} = \sqrt{33.9\times 32.3}\Omega = 33.09\Omega$$

$$e_1 = (30\times 0.001 + 3\times 0.005 + 0.9\times 0.02 + 0.012)\Omega = 0.075\Omega$$

$$e_2 = (30\times 0.001 + 2\times 0.005 + 0.3\times 0.02 + 0.012)\Omega = 0.058\Omega$$

$$\delta_{R_{x1}} = \frac{0.2R_{x1}}{S} = \frac{0.2\times 33.9}{44.07}\Omega = 0.1538\Omega$$

$$\delta_{R_{x2}} = \frac{0.2R_{x2}}{S} = \frac{0.2\times 32.3}{41.53}\Omega = 0.1555\Omega$$

$$\sigma_{R_{x1}} = \sqrt{\delta_{R_{x1}}^2 + \frac{e_1^2}{3}} = \sqrt{0.1538^2 + \frac{0.075^2}{3}}\Omega = 0.1598\Omega$$

$$\sigma_{R_{x2}} = \sqrt{\delta_{R_{x2}}^2 + \frac{e_2^2}{3}} = \sqrt{0.1555^2 + \frac{0.058^2}{3}}\Omega = 0.1590\Omega$$

$$\frac{\sigma_{R_x}}{R_x} = \sqrt{\left(\frac{\sigma_{R_{x1}}}{2R_{x1}}\right)^2 + \left(\frac{\sigma_{R_{x2}}}{2R_{x2}}\right)^2} = \sqrt{\left(\frac{0.1598}{2\times 33.9}\right)^2 + \left(\frac{0.1590}{2\times 32.3}\right)^2}\Omega = 3.4\times 10^{-3}$$

$$\sigma_{R_x} = 33.09\Omega\times 3.4\times 10^{-3} = 0.11\Omega$$

结果为：

$$R_x = (33.09 \pm 0.11)\Omega$$

3. 计算测得的各个电阻值的不确定度。

R_{x3}

$$e_3 = (30 \times 0.001 + 3 \times 0.005 + 0.012)\Omega = 0.057\Omega$$

$$\delta_{R_{x3}} = \frac{0.2R_{x3}}{S} = \frac{0.2 \times 33.0}{2607}\Omega = 2.532 \times 10^{-3}\Omega$$

$$\sigma_{R_{x3}} = \sqrt{\delta_{R_{x3}}^2 + \frac{e_3^2}{3}} = \sqrt{0.002532^2 + \frac{0.057^2}{3}}\Omega = 0.03\Omega$$

R_{x4}

$$e_4 = (330 \times 0.001 + 3 \times 0.005 + 0.2 \times 0.02 + 0.012)\Omega = 0.361\Omega$$

$$\delta_{R_{x3}} = \frac{0.2R_{x3}}{S} = \frac{0.2 \times 33.32}{764.06}\Omega = 8.72 \times 10^{-3}\Omega$$

$$\sigma_{R_{x3}} = \sqrt{\delta_{R_{x3}}^2 + \frac{e_3^2}{3}} = \sqrt{0.00872^2 + \frac{0.361^2}{3}}\Omega = 0.2\Omega$$

R_{x5}

$$e_5 = (30 \times 0.001 + 3 \times 0.005 + 0.4 \times 0.02 + 0.012)\Omega = 0.065\Omega$$

$$\delta_{R_{x3}} = \frac{0.2R_{x5}}{S} = \frac{0.2 \times 33.4}{83.5}\Omega = 0.08\Omega$$

$$\sigma_{R_{x3}} = \sqrt{\delta_{R_{x3}}^2 + \frac{e_3^2}{3}} = \sqrt{0.08^2 + \frac{0.065^2}{3}}\Omega = 0.09\Omega$$

R_{x6}

$$e_6 = (30 \times 0.001 + 3 \times 0.005 + 0.4 \times 0.02 + 0.012)\Omega = 0.065\Omega$$

$$\delta_{R_{x6}} = \frac{0.2R_{x6}}{S} = \frac{0.2 \times 33.4}{1336}\Omega = 5 \times 10^{-3}\Omega$$

$$\sigma_{R_{x3}} = \sqrt{\delta_{R_{x3}}^2 + \frac{e_3^2}{3}} = \sqrt{0.005^2 + \frac{0.065^2}{3}}\Omega = 0.04\Omega$$

非平衡电桥测铂电阻的温度系数

一、数据处理

1．画电路图，连接非平衡电桥测温电路，铂电阻传感器使用三线接法。设置电源电压为 19 伏，电桥桥臂阻值 R1 和 R2 均为 10k 欧姆，记录这些条件参数（实测值）。让铂电阻温度为水的冰点，此时调节电桥平衡。记录数据。

表 1 条件及冰点电阻值

项目	E	R_1	R_2	冰点平衡R_0
数据	18.994V	10.225kΩ	9.965 kΩ	97.7Ω

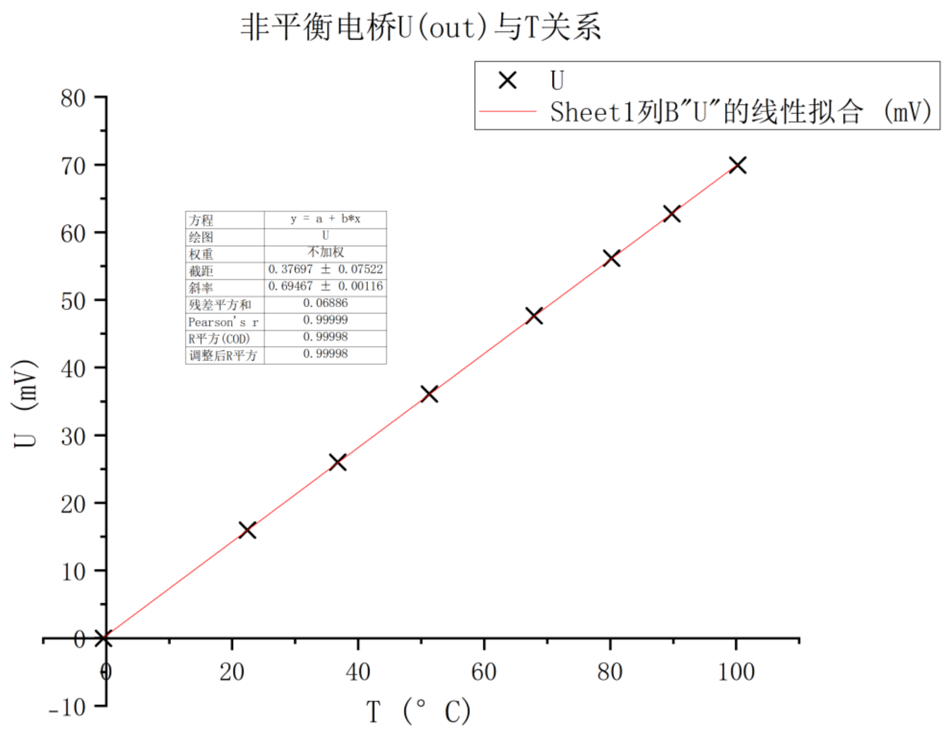
2．逐步改变铂电阻的温度直至水的沸点，记录其温度和电桥非平衡电压的系列数据。

表 2 T-U_{out}数据

T/ °C	-0.4	22.45	36.74	51.3	67.92	80.26	89.81	100.27
U_{out}/V	-0.04	15.97	25.99	36.12	47.66	56.15	62.72	69.9

3．对非平衡电桥测温电路的输出～输入曲线作图，作线性拟合，记录拟合直线方程、方程系数和相关系数。 计算测温电路灵敏度。

图 1 T-U_{out}曲线



无量纲化后方程（原单位）$U = 0.69467T + 0.37697$

$k = 0.69467 \pm 0.00116$,　　$b = 0.37697 \pm 0.07522$

r=0.99999

灵敏度$K = \frac{dU}{dT} = 0.69467 mV/°C$

4．推导稳压电源情况下的铂电阻温度系数 A1 理论公式，由输出~输入曲线线性拟合的斜率

计算铂电阻温度系数 A1 ，（选做）估计其不确定度。将测量结果与参考值比较。

由基尔霍夫定律：$\mathrm{U_{out}} = \mathrm{E}\frac{\mathrm{R_2R_T-R_1R_P}}{\mathrm{(R_1+R_T)(R_2+R_P)}}$,

则$\frac{d\mathrm{U_{out}}}{d\mathrm{R_T}} = E\frac{\mathrm{R_1}}{\mathrm{(R_1+R_T)^2}}$,

代入数据，$\frac{d\mathrm{U_{out}}}{d\mathrm{R_T}} = 18.994 \times \frac{10225}{(10225+97.7)^2} V/\Omega = 1.8226 \times 10^{-3} V/\Omega$.

结合$\frac{d\mathrm{U_{out}}}{dT} = \frac{d\mathrm{U_{out}}}{d\mathrm{R_T}}\frac{d\mathrm{R_T}}{dT}$，及$\frac{d\mathrm{U_{out}}}{dT} = 6.9467 \times 10^{-4}\mathrm{V/℃}$,

得$\frac{d\mathrm{R_T}}{dT} = \frac{6.9467\times10^{-4}\mathrm{V/℃}}{1.8226\times10^{-3}V/\Omega} = 0.381142\Omega/℃$,

则$A_1 = \frac{\frac{d\mathrm{R_T}}{dT}}{R_0} = \frac{0.381142\Omega/℃}{97.7\Omega} = 3.9011 \times 10^{-3}℃^{-1}$.

计算不确定度：上述过程中$A_1 = k\frac{\mathrm{(R_1+R_0)^2}}{E\mathrm{R_1R_0}}$

$$\sigma_\mathrm{k} = 0.00116$$

$$\sigma_{\mathrm{R_1}} = \frac{0.002 \times 10.225 + 0.005}{\sqrt{3}}\mathrm{k}\Omega = 0.014694\mathrm{k}\Omega = 14.694\Omega$$

$$\sigma_{\mathrm{R_0}} = \frac{90 \times 0.001 + 7 \times 0.005 + 0.7 \times 0.02 + 0.012}{\sqrt{3}} = 0.087180\Omega$$

$$\sigma_\mathrm{E} = \frac{0.0005 \times 18.994 + 0.003}{\sqrt{3}}\mathrm{V} = 7.2151 \times 10^{-3}\mathrm{V}$$

$$\sigma_{\frac{\mathrm{(R_1+R_0)^2}}{\mathrm{R_1R_0}}} = \sqrt{(-\frac{\mathrm{R_1}}{R_0^2} + \frac{1}{\mathrm{R_1}})^2\sigma_{\mathrm{R_0}}^2 + (-\frac{\mathrm{R_0}}{R_1^2} + \frac{1}{\mathrm{R_0}})^2\sigma_{\mathrm{R_1}}^2} = 0.17702\Omega$$

$$\frac{\sigma_{A_1}}{A_1} = \sqrt{\left(\frac{\sigma_{\frac{\mathrm{(R_1+R_0)^2}}{\mathrm{R_1R_0}}}}{\frac{\mathrm{(R_1+R_0)^2}}{\mathrm{R_1R_0}}}\right)^2 + \left(\frac{\sigma_\mathrm{E}}{E}\right)^2 + \left(\frac{\sigma_\mathrm{k}}{k}\right)^2} = 2.4 \times 10^{-3}$$

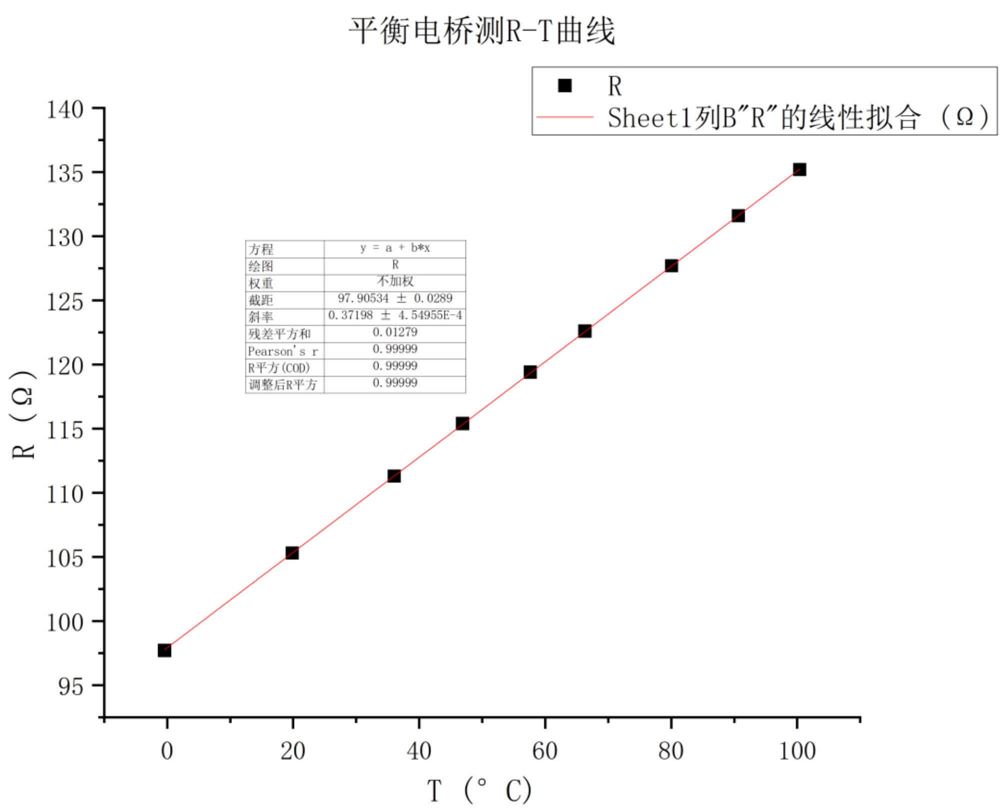
$$A_1 = (3.901 \pm 0.009) \times 10^{-3}℃^{-1}$$

5. 用平衡桥测量铂电阻温度系数 A1 。

表 3 平衡电桥测温度系数

T/ °C	-0.4	19.86	36.03	46.91	57.63	66.32	80.07	90.67	100.39
U_{out}/V	97.7	105.3	111.3	115.4	119.4	122.6	127.7	131.6	135.2

图 2 R-T 曲线



以最小二乘法拟合：$k = 0.37198 \pm 4.54955E-4$

$$A_1 = \frac{\frac{dR_T}{dT}}{R_0} = \frac{0.37198\Omega/℃}{97.7\Omega} = 3.81 \times 10^{-3}℃^{-1}$$

不确定度：

$$\sigma_{R_0} = \frac{90 \times 0.001 + 7 \times 0.005 + 0.7 \times 0.02 + 0.012}{\sqrt{3}} = 0.087180\,\Omega$$

$$\sigma_k = 4.54955 \times 10^{-4}\Omega/℃$$

$$\frac{\sigma_{A_1}}{A_1} = \sqrt{\left(\frac{\sigma_{R_0}}{R_0}\right)^2 + \left(\frac{\sigma_k}{k}\right)^2} = 9 \times 10^{-3}$$

$$\sigma_{A_1} = 9 \times 10^{-3} \times 3.81 \times 10^{-3}℃^{-1} = 3.4 \times 10^{-2} \times 10^{-3}℃^{-1}$$

最终结果为：$A_1 = (3.81 \pm 0.03) \times 10^{-3}℃^{-1}$

二、收获与感想

由于预习时间距离正式实验较久，遗忘了实验内容，第一次操作时做成了平衡电桥相关操作，导致实验完成时间推迟较久。但好在平衡电桥的实验也得出铂电极的温度系数，且理论值落在了两次实验结果的区间内，得到了印证。今后在实验前应当对实验步骤及目的有更好地把握。