Design a Digital Weighing Scale using Strain Gauges

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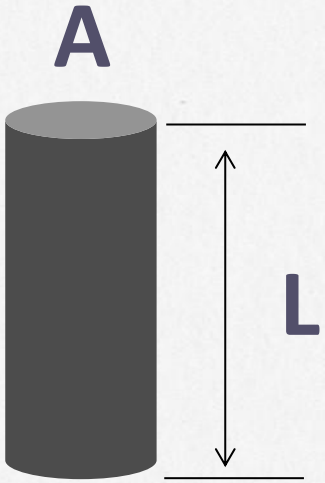
Weighing Scale

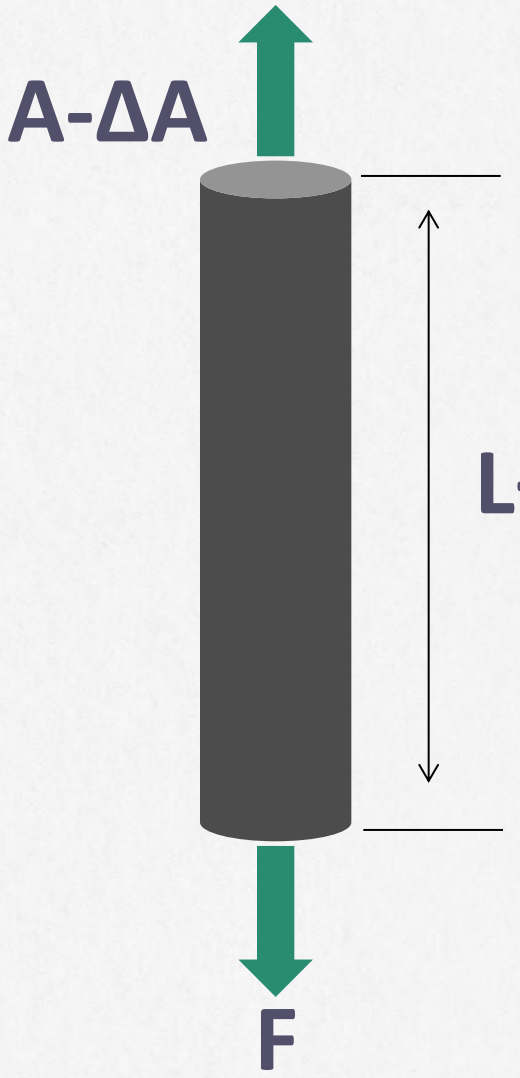
Balance Scale

Digital Scale

What is a Strain Gauge?



$$R = \rho \frac{L}{A}$$



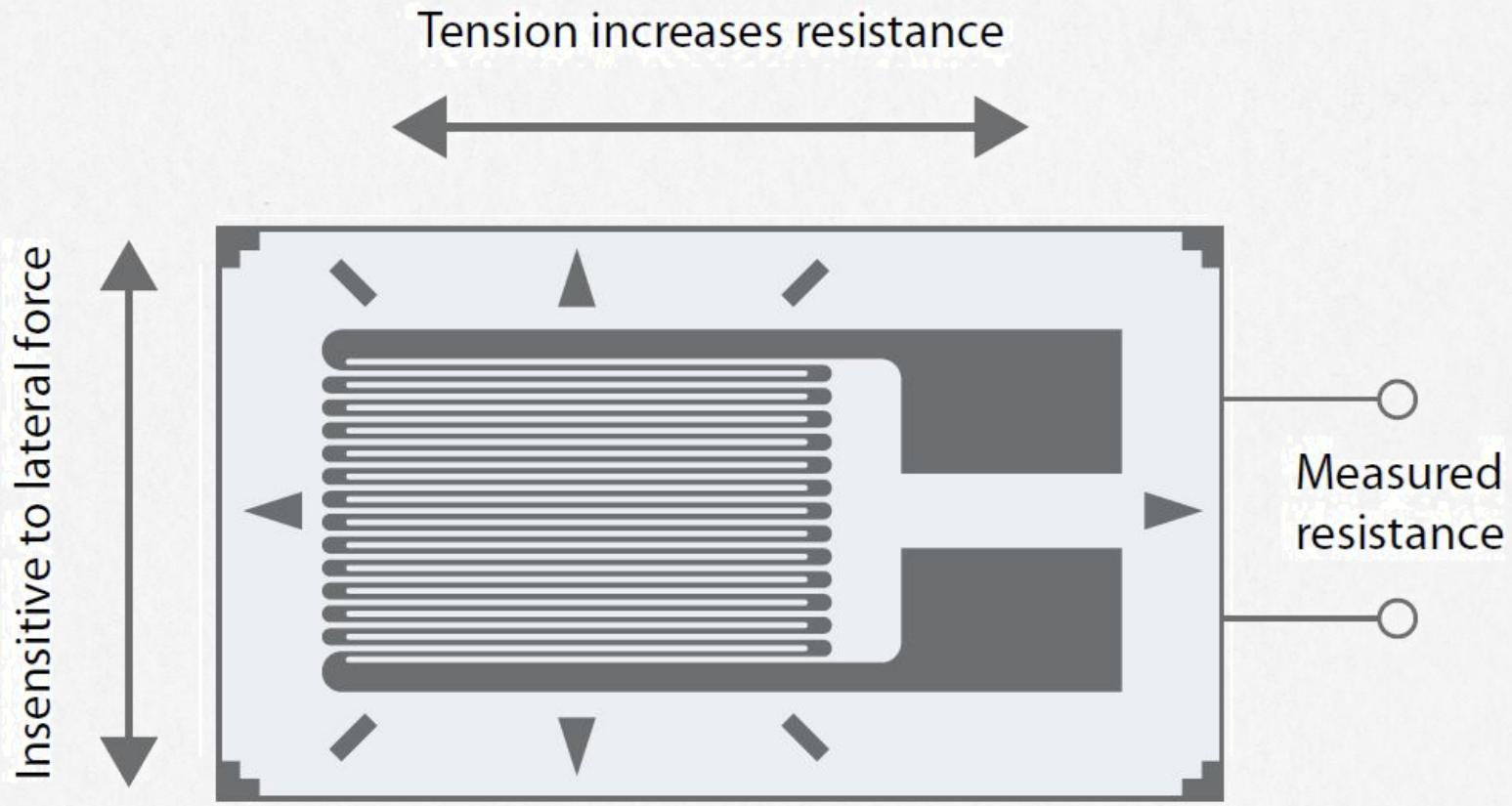
$$\frac{\Delta R}{R} = k_m \frac{\Delta L}{L} = k_m \varepsilon$$

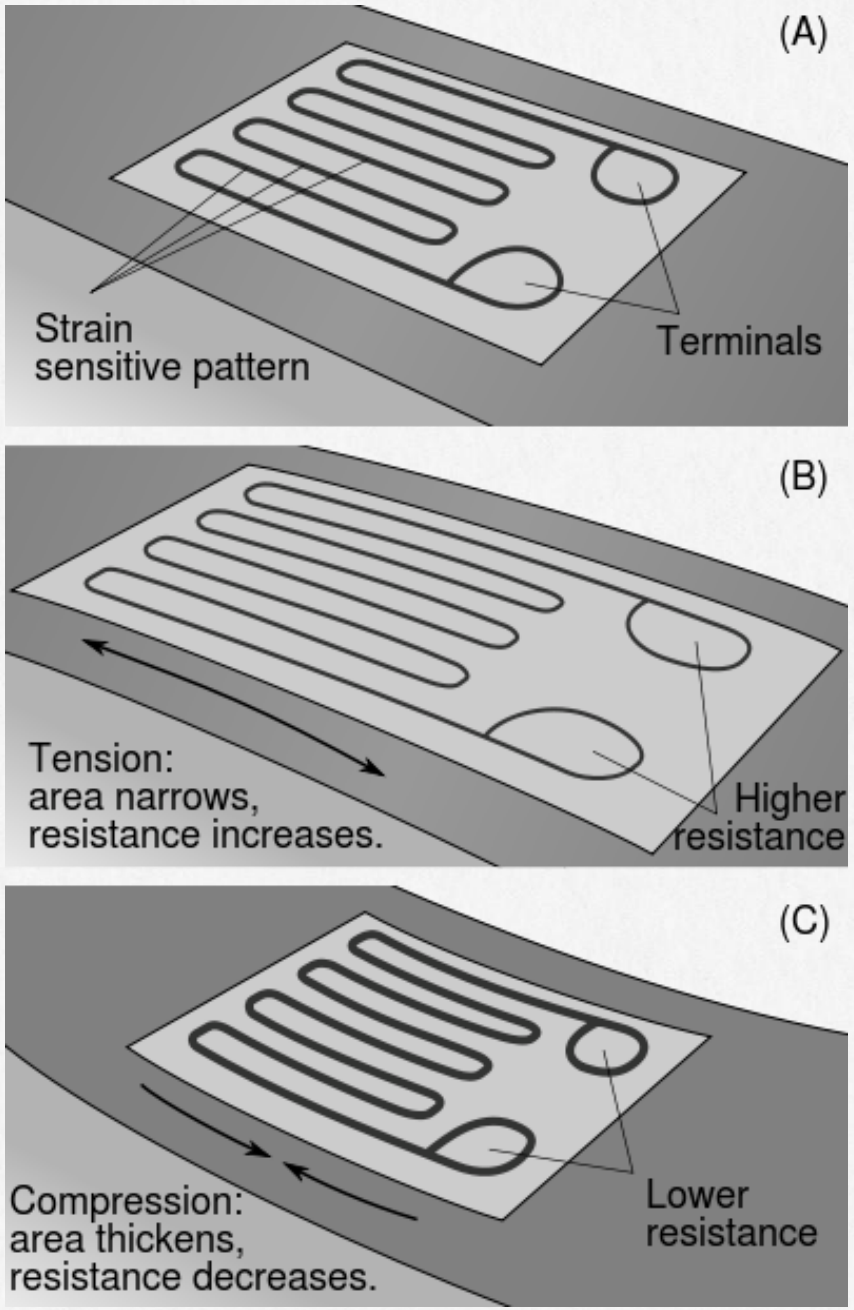
R: Resistance
ρ: Resistivity
L: Length
A: Area

k_m: Gauge factor
$\epsilon = \frac{\Delta L}{L}$: Strain

ΔR is usually very small

Foil Strain Gauge

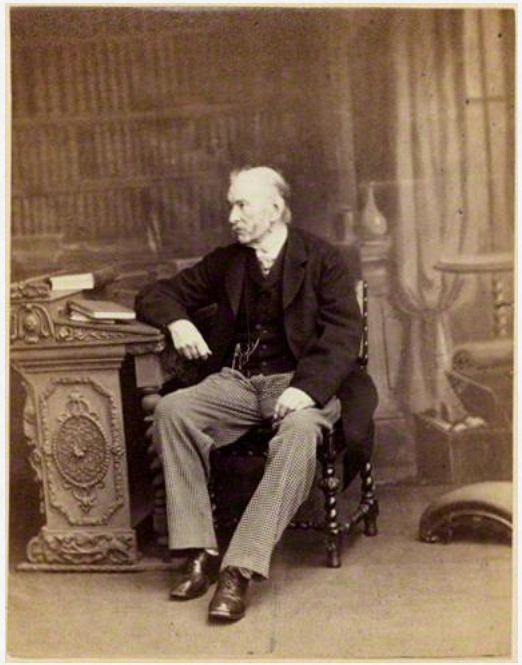




Why zigzag?

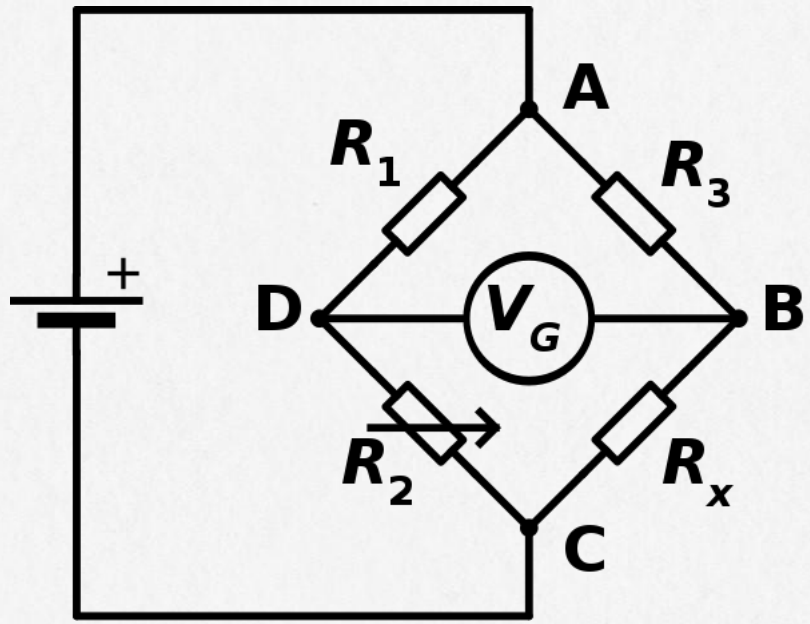
ΔR is usually very small

How to measure ΔR?



Samuel Hunter Christie Sir Charles Wheatstone

Wheatstone bridge

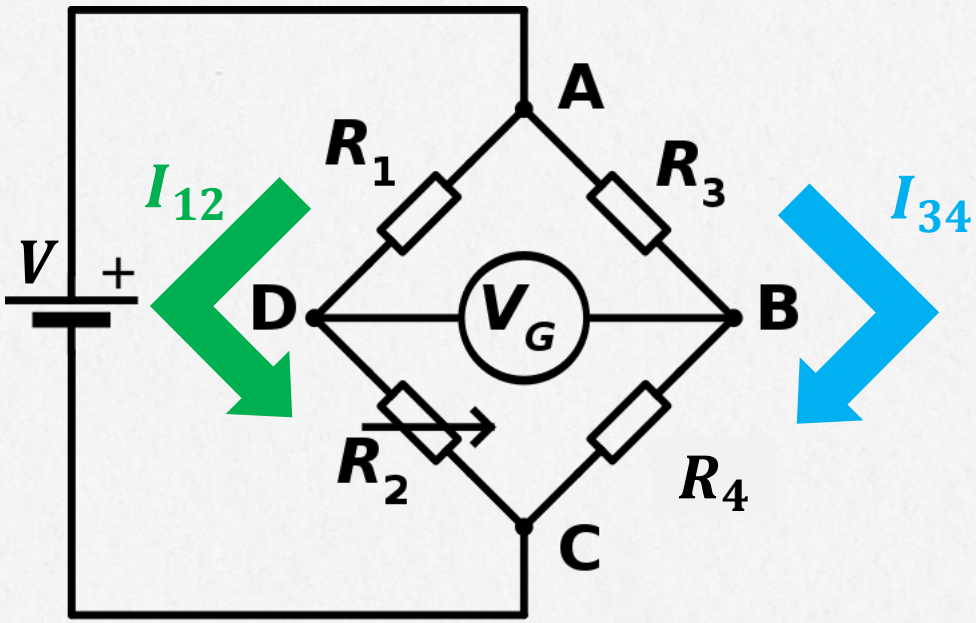


$$V_G = 0 \qquad \frac{R_2}{R_1} = \frac{R_x}{R_3}$$

Device Under Test (DUT): $R_x = R_3 \dfrac{R_2}{R_1}$

ΔR is usually very small

How to measure ΔR?



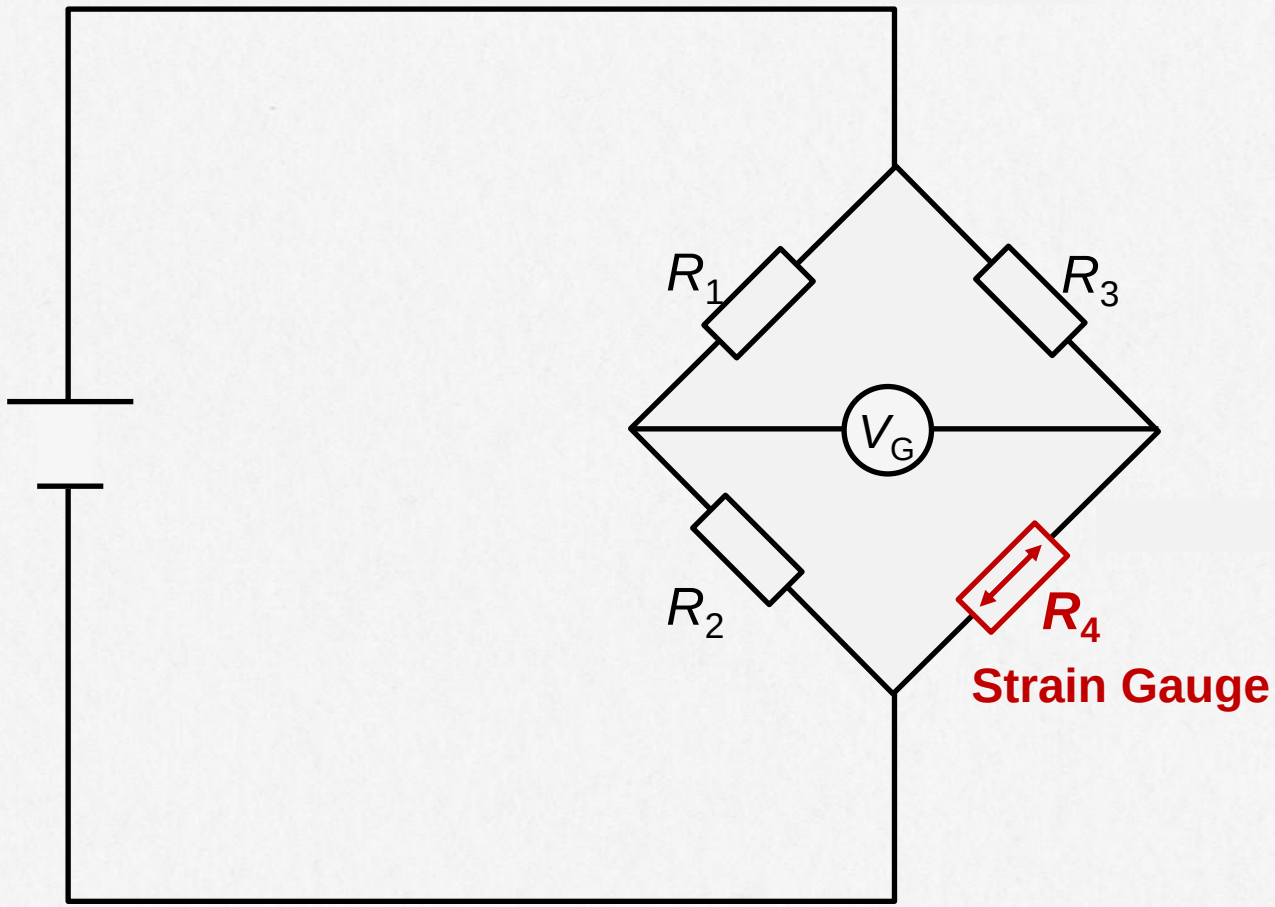
$$I_{12} = \frac{V}{R_1 + R_2} \qquad I_{34} = \frac{V}{R_3 + R_4}$$

$$V_D - V_A = I_{12}R_1 = \frac{VR_1}{R_1 + R_2}$$

$$V_B - V_A = I_{34}R_3 = \frac{VR_3}{R_3 + R_4}$$

$$V_G = V_B - V_D = \frac{R_1R_4 - R_2R_3}{(R_1+R_2)(R_3 + R_4)}$$

Quarter bridge



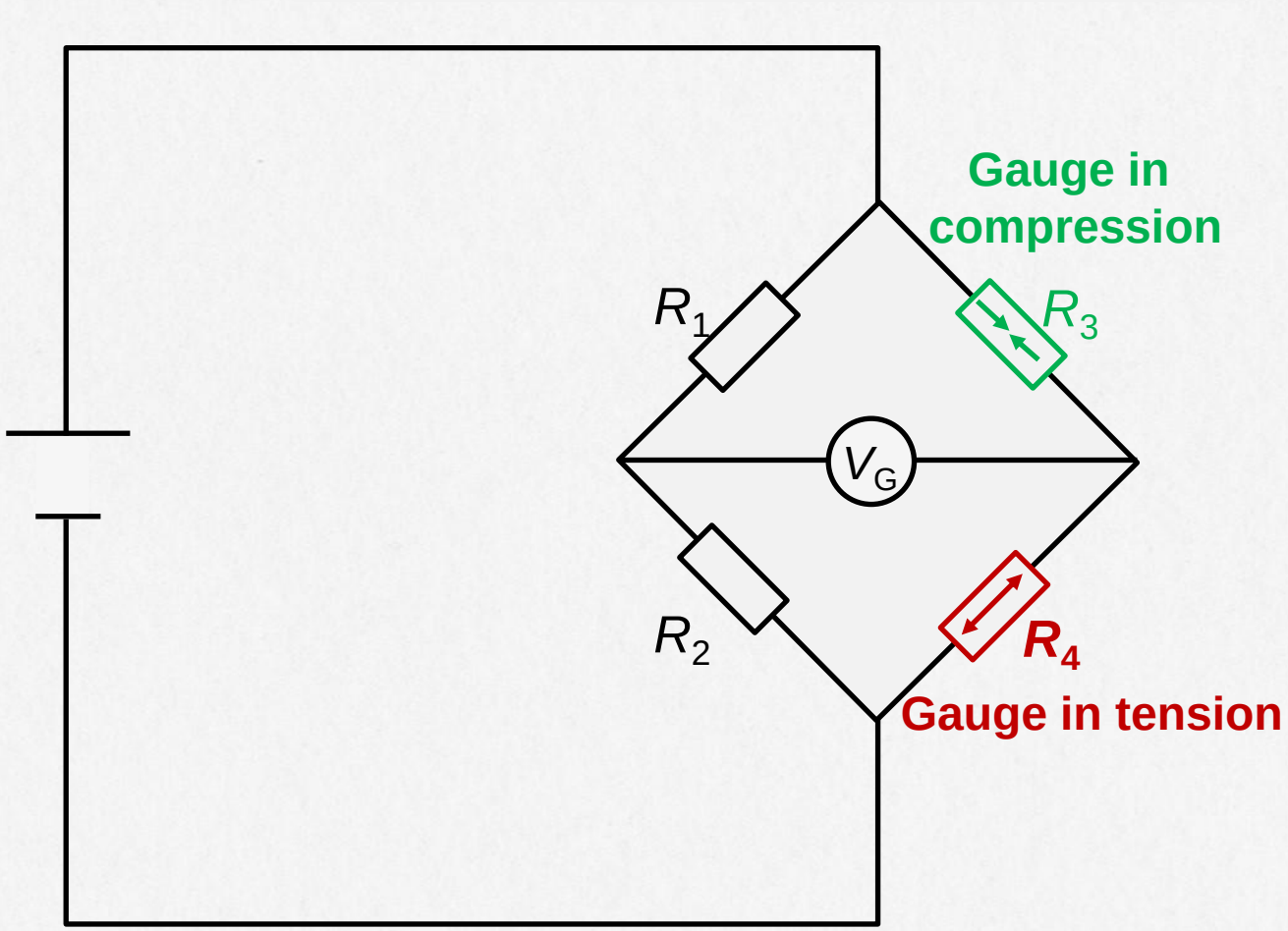
$$V_G = V_B - V_D = \frac{R_1R_4 - R_2R_3}{(R_1+R_2)(R_3+R_4)}$$

$$R_1 = R_2 = R_3 = R_4 = R$$

Apply strain $R_4 = R + \Delta R$

$$V_G = \frac{V}{4}\frac{\Delta R}{R}$$

Half bridge



$$V_G = V_B - V_D = V\frac{R_1R_4 - R_2R_3}{(R_1+R_2)(R_3+R_4)}$$

$$R_1 = R_2 = R_3 = R_4 = R$$

Apply strain $R_3 = R - \Delta R$

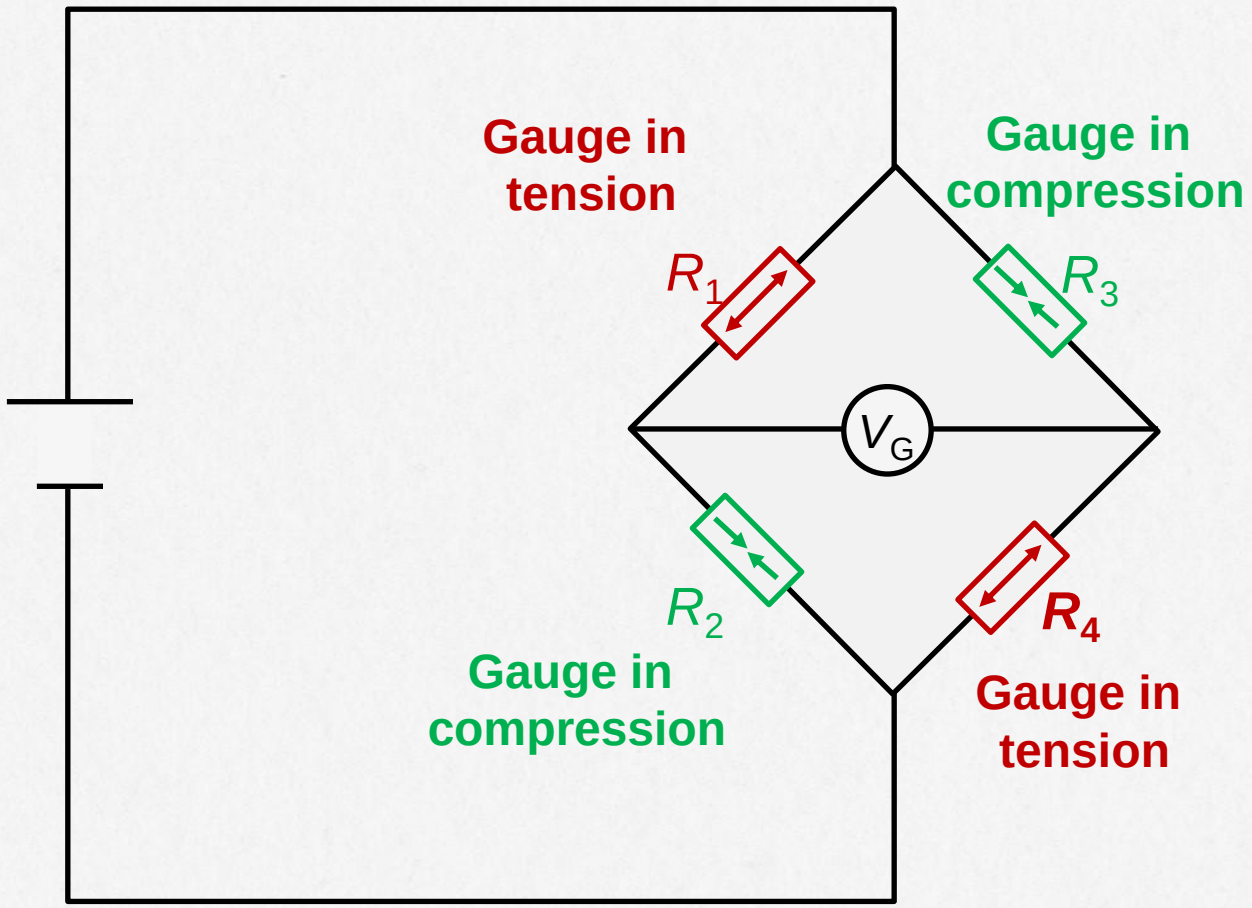
$$R_4 = R + \Delta R$$

$$V_G = \frac{V}{2}\frac{\Delta R}{R}$$

Full bridge

ΔR

Same sign on cross arms!
Opposite sign on neighboring arms !



$$V_G = V_B - V_D = \frac{R_1R_4 - R_2R_3}{(R_1+R_2)(R_3+R_4)}$$

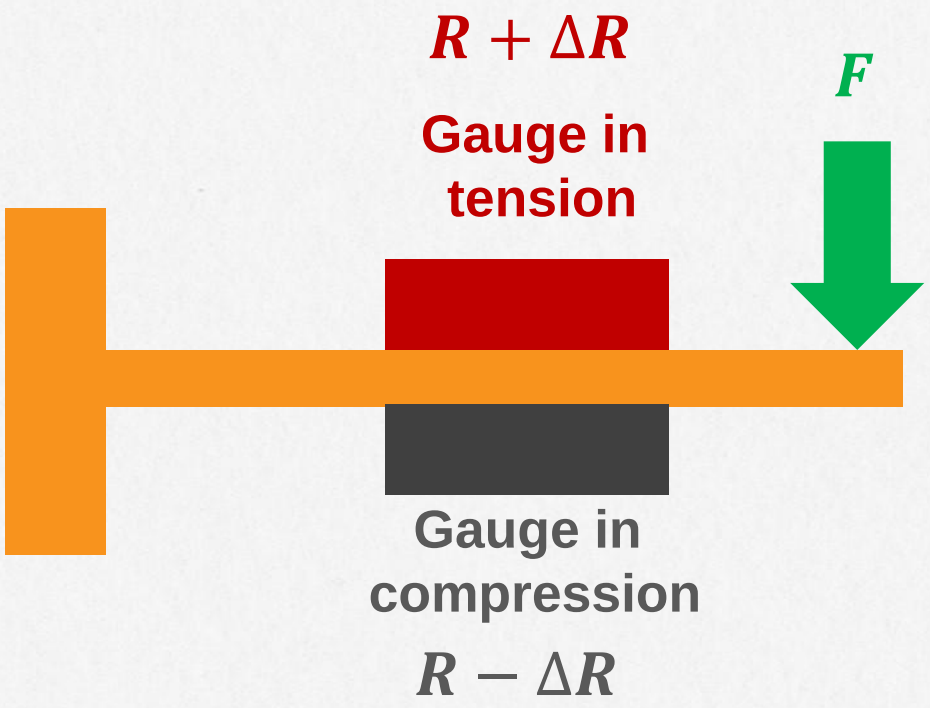
$$R_1 = R_2 = R_3 = R_4 = R$$

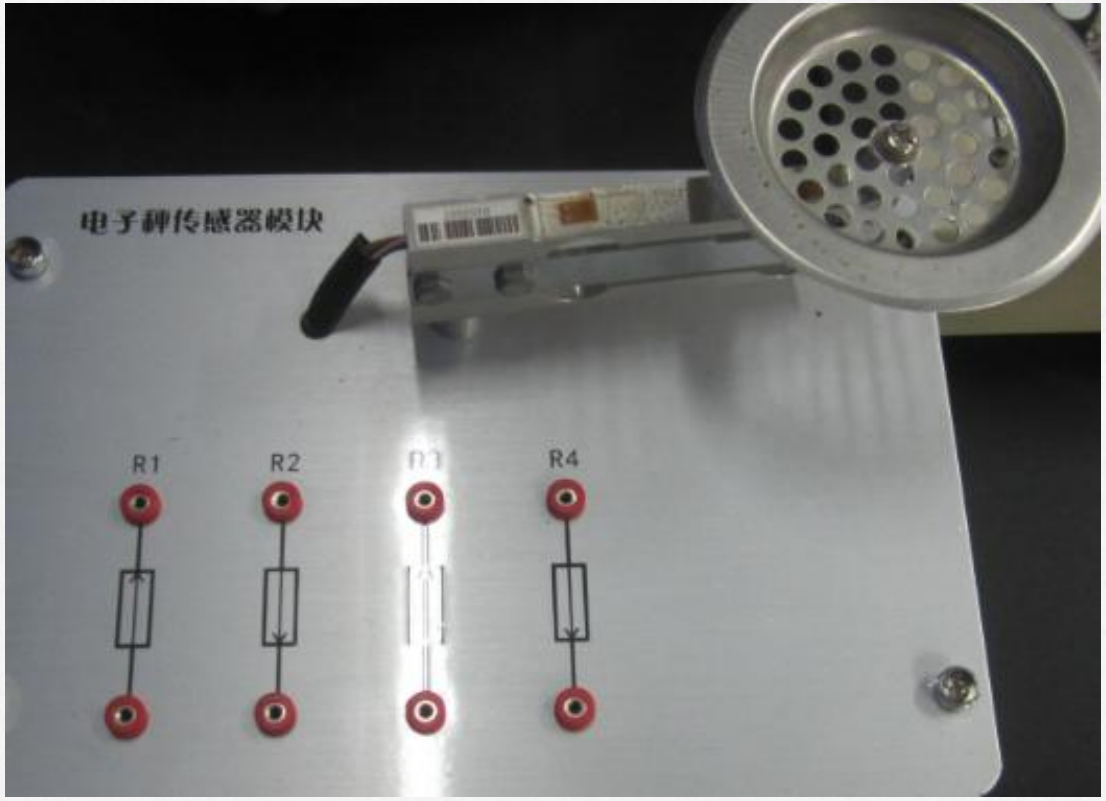
Apply strain

$$R_1 = R + \Delta R$$
$$R_2 = R - \Delta R$$
$$R_3 = R - \Delta R$$
$$R_4 = R + \Delta R$$

$$V_G = V\frac{\Delta R}{R}$$

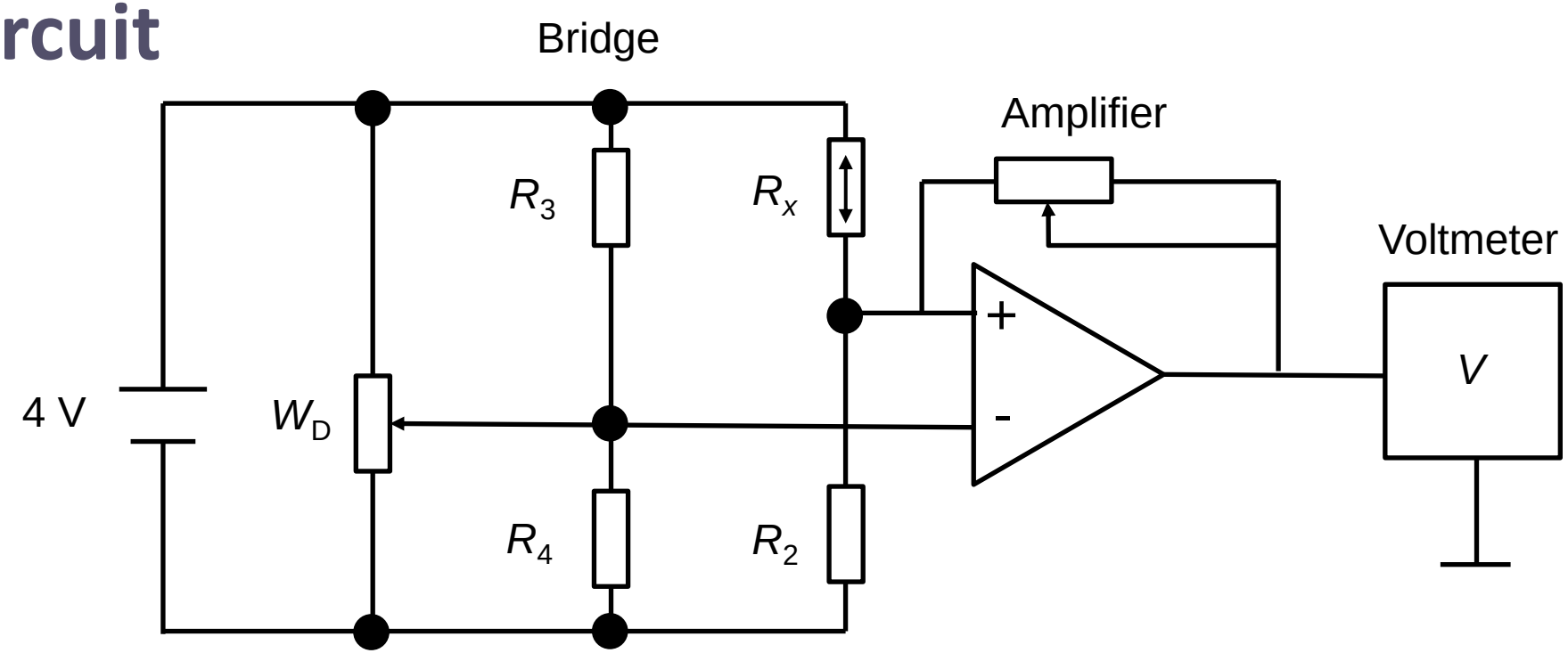
Experimental setup

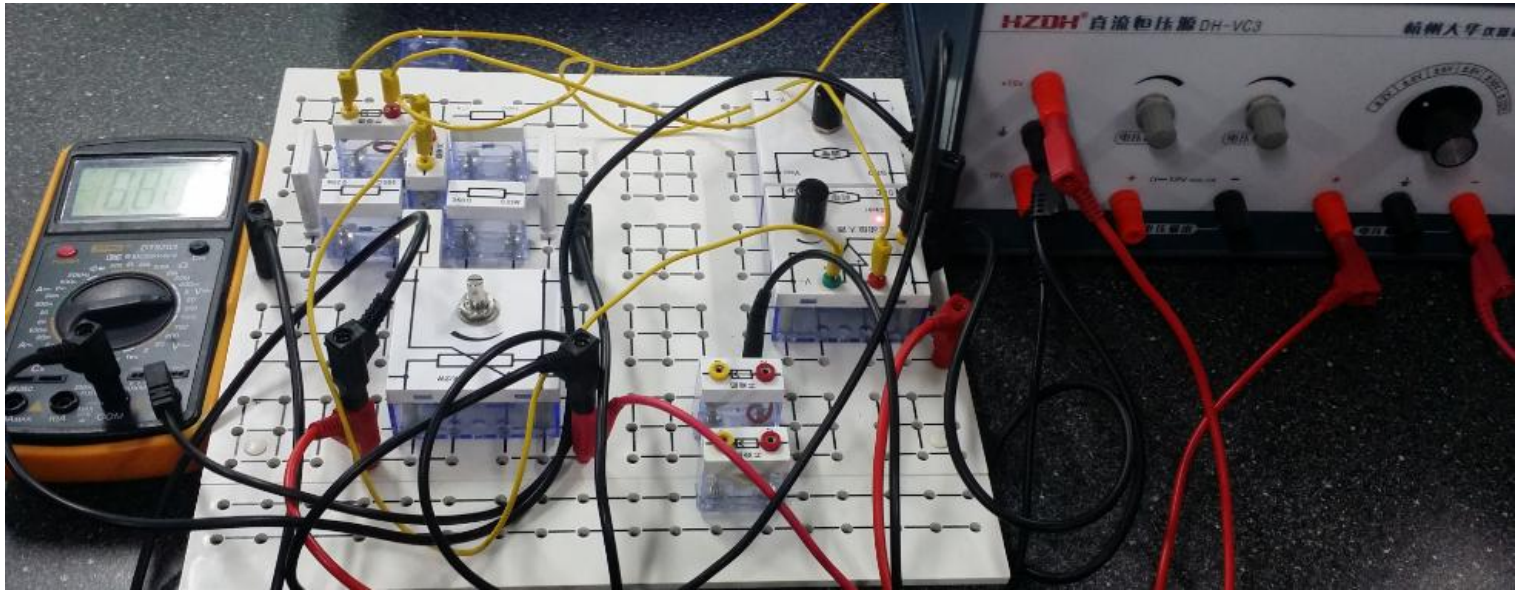




Cantilever

Bridge Circuit





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Time for fun!

1.Safety

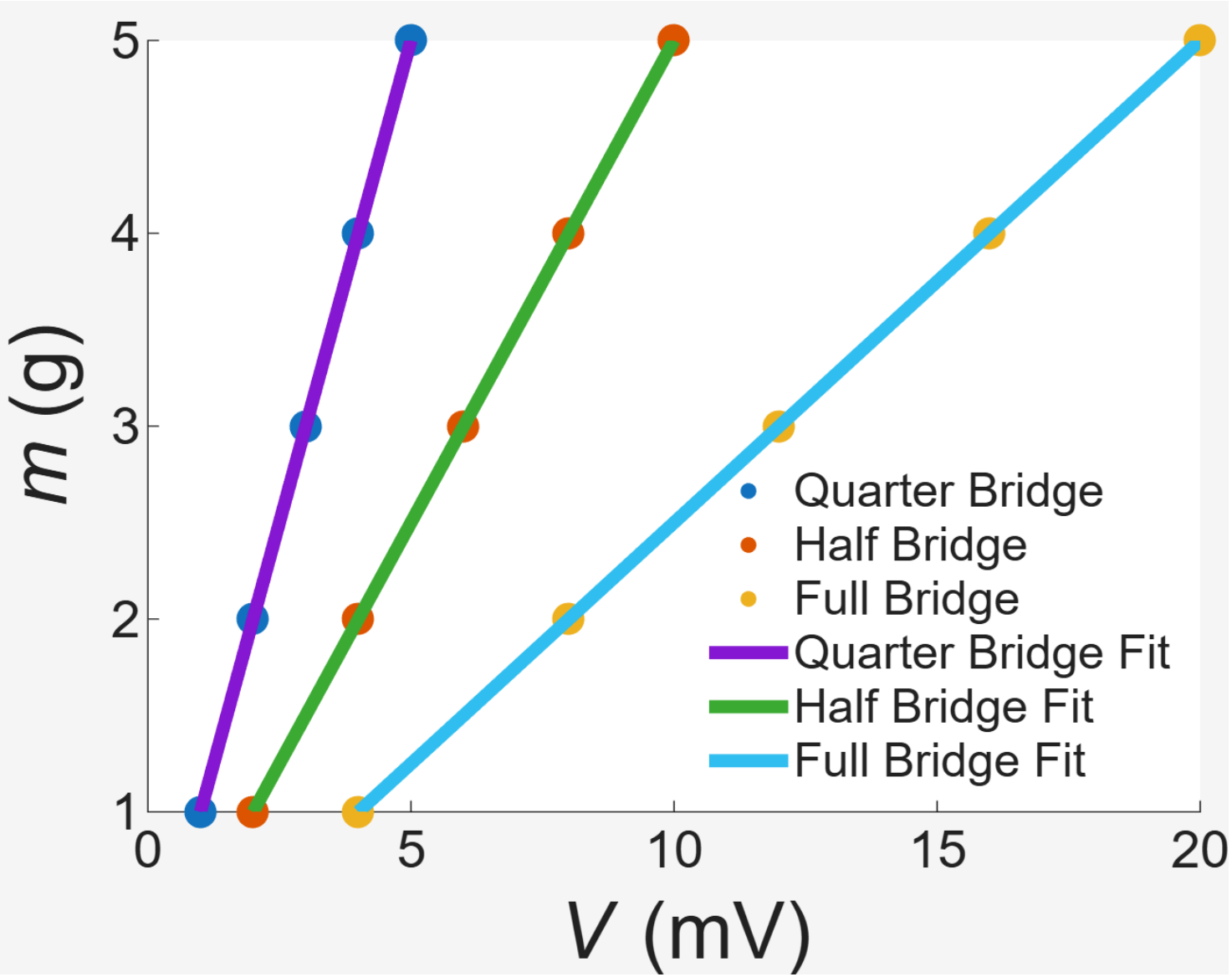
- **Do not touch the output ends of the power supply directly.**
- **Do not short the two output ends of the power supply.**
- **Turn on the power supply only after the circuit is ready.**

2.Data recording form

Appendix Table I: Experimental Raw Data

	Load(g)	V_1 (mV)	V_2 (mV)	V_3 (mV)	V_4 (mV)	V_5 (mV)	Mean V_G(mV)
Quarter Bridge							
	Your Phone						

Data Analysis



Data Analysis

```
m=[1,2,3,4,5]; %砝码质量，单位g
Vq=[1,2,3,4,5]; %quarter bridge电压读数,单位是mV
Vh=[2,4,6,8,10]; %half bridge电压读数,单位是mV
Vf=[4,8,12,16,20]; %full bridge电压读数,单位是mV
pq=polyfit(Vq,m,1); %quarter bridge线性拟合，pq(1)是斜率
fitq=polyval(pq,Vq); %计算quarter bridge拟合数据
ph=polyfit(Vh,m,1); %half bridge线性拟合，ph(1)是斜率
fith=polyval(ph,Vh); %计算half bridge拟合数据
pf=polyfit(Vf,m,1); %half bridge线性拟合，ph(1)是斜率
fitf=polyval(pf,Vf); %计算full bridge拟合数据
figure; %开始画图
scatter(Vq,m,150,'filled','DisplayName','Quarter Bridge'); %画quarter bridge原始数据散点
hold on;
scatter(Vh,m,150,'filled','DisplayName','Half Bridge'); %画half bridge原始数据散点
hold on;
scatter(Vf,m,150,'filled','DisplayName','Full Bridge'); %画full bridge原始数据散点
hold on; %不关图，后面还要画拟合线
plot(Vq,fitq,'LineWidth',5,'DisplayName','Quarter Bridge Fit'); %画拟合线
plot(Vh,fith,'LineWidth',5,'DisplayName','Half Bridge Fit'); %画拟合线
plot(Vf,fitf,'LineWidth',5,'DisplayName','Full Bridge Fit'); %画拟合线
set(gca,'FontName','Arial','FontSize',20); %设置图横纵坐标的字体大小
xlabel('{\it V} (mV)','FontSize',30); %设置横坐标label及字体大小
ylabel('{\it m} (g)','FontSize',30); %设置纵坐标label及字体大小
legend('Location','southeast');%画图标位置
legend('boxoff')
hold off
```

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THANK YOU!