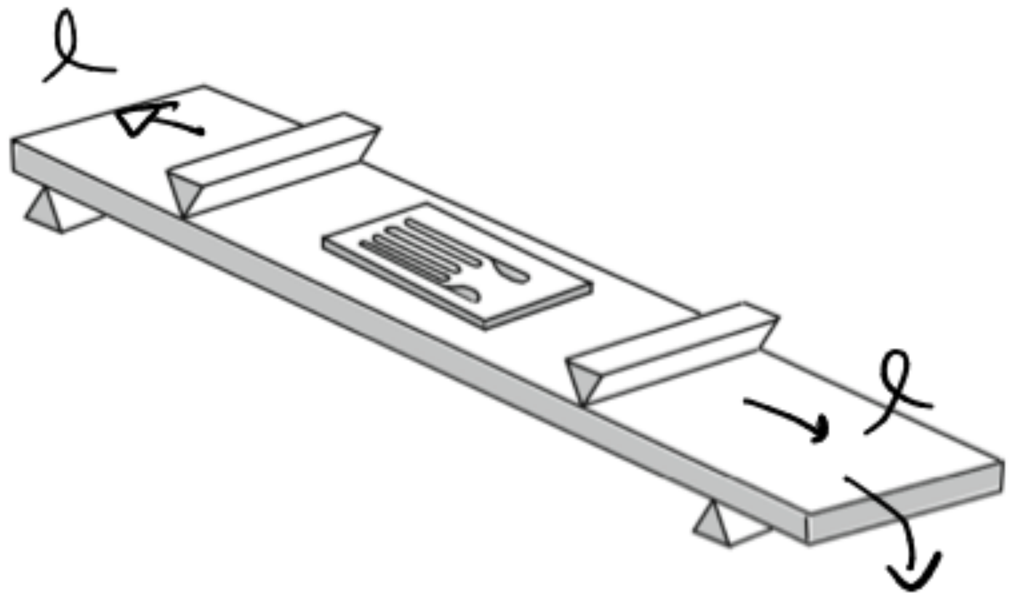
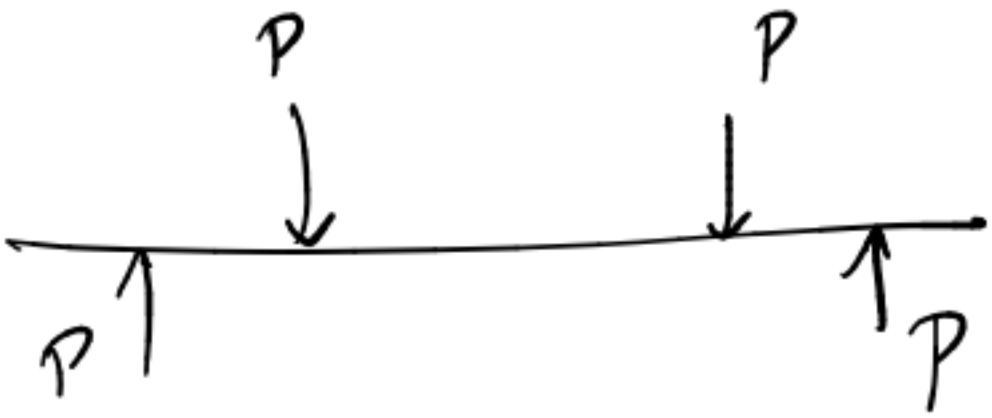
AS3520

Lecture 3

- Transverse sensitivity of strain gauges.
- Calibration of strain gauges.

Fig. 2.5 Device for gage calibration





$\nu = 0.285$

P — known force induces known bending moment M in the beam.

$$\rightarrow \sigma_{xx} = \frac{My}{I} \rightarrow \varepsilon_{xx} = \frac{My}{EI}$$

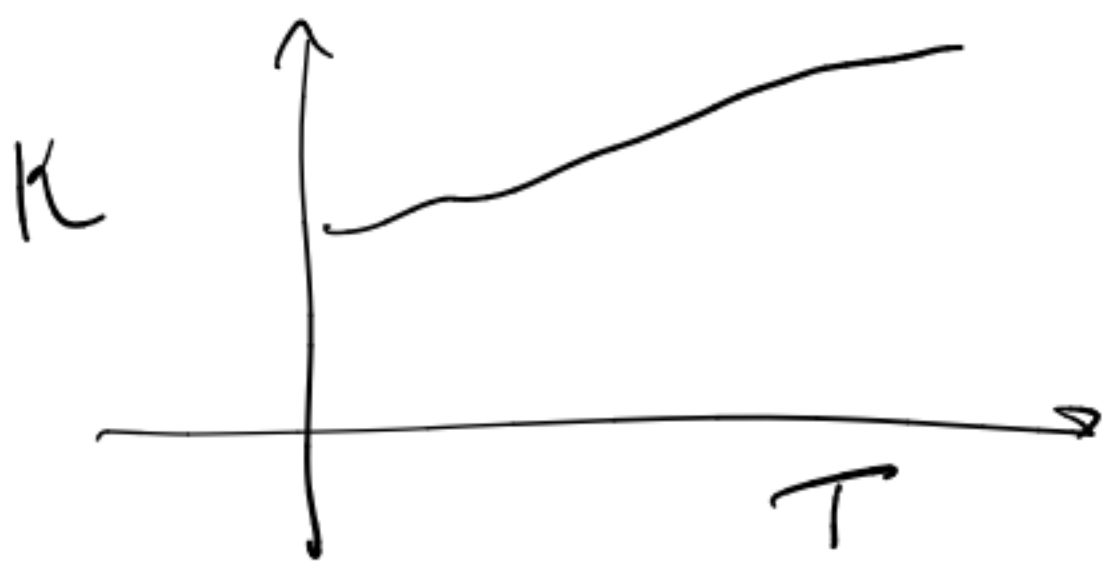
$$\frac{\Delta R}{R} \longrightarrow \text{measured.}$$

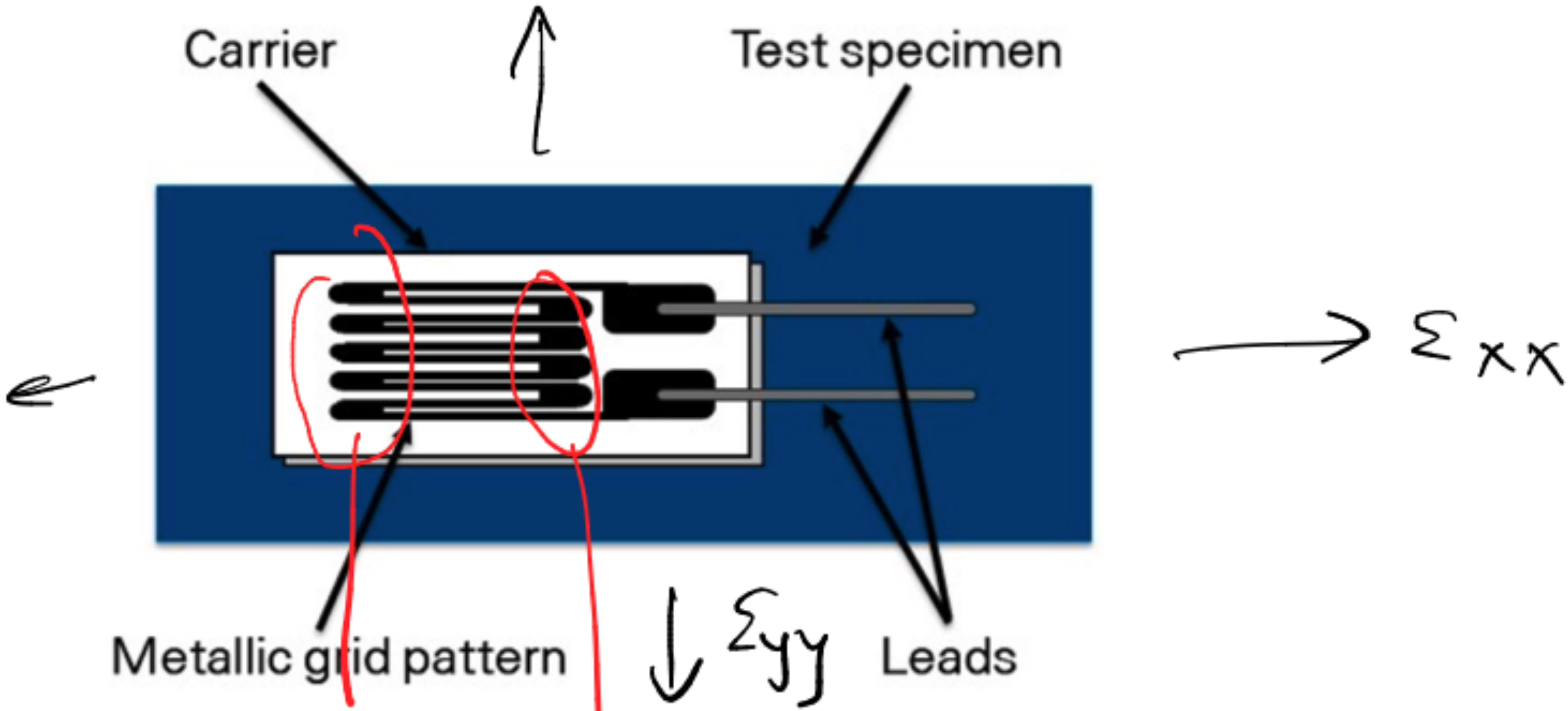
$$\frac{\Delta R}{R} = K \, \varepsilon_{xx}$$

known from measurement

calibrated gauge factor / sensitivity of the strain gauge.

known from P





slightly affected by transverse strains (ε_{yy}). To account for ε_{yy} dependence, write:

$$\frac{\Delta R}{R} = S_a \, \varepsilon_{xx} + S_t \, \varepsilon_{yy}$$

S_a: axial gauge factor

S_t: transverse gauge factor.

Usually $S_t << S_a$.

$$\frac{\Delta R}{R} = S_a \left(\varepsilon_{xx} + K_t \frac{\varepsilon_{yy}}{\varepsilon_{xx}} \right)$$

K_t: transverse sensitivity, S_t / S_a.

During the calibration test,

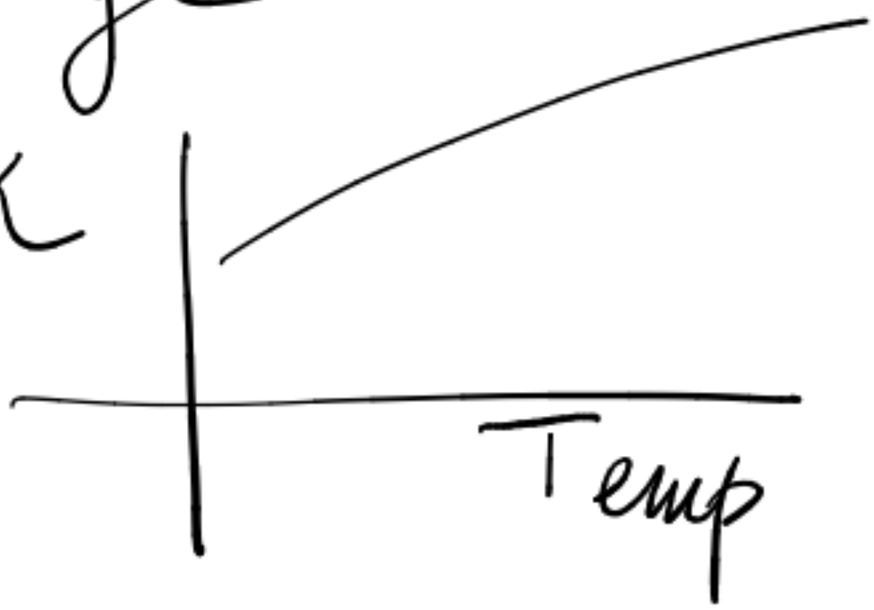
$$\varepsilon_{yy} = -\nu\,\varepsilon_{xx}$$

$$\Rightarrow \frac{\Delta R}{R} = S_a\left(\varepsilon_{xx} \mp K_t\,\nu\,\varepsilon_{xx}\right)$$

$$\frac{\Delta R}{R} = \underbrace{S_a\left(1 - K_t\,\overset{0.285}{\nu}\right)}_{\text{Reported gauge factor}}\varepsilon_{xx}$$

K of the strain gauge

$$S_a(1 - K_t\,\nu) = K$$



Sharing: a TN from Vishay PG on transverse strain sensitivity correction during biaxial tests.

Thermal o/P of strain gauge

$R = 120\,\Omega,\ 350\,\Omega,\ \ldots$

$$\left.\begin{array}{l}\text{Current} \le 20\text{ mA.} \\ \text{Typical} \approx 10-15\text{ mA.}\end{array}\right\}\ \text{to prevent excessive Joule heating.}$$

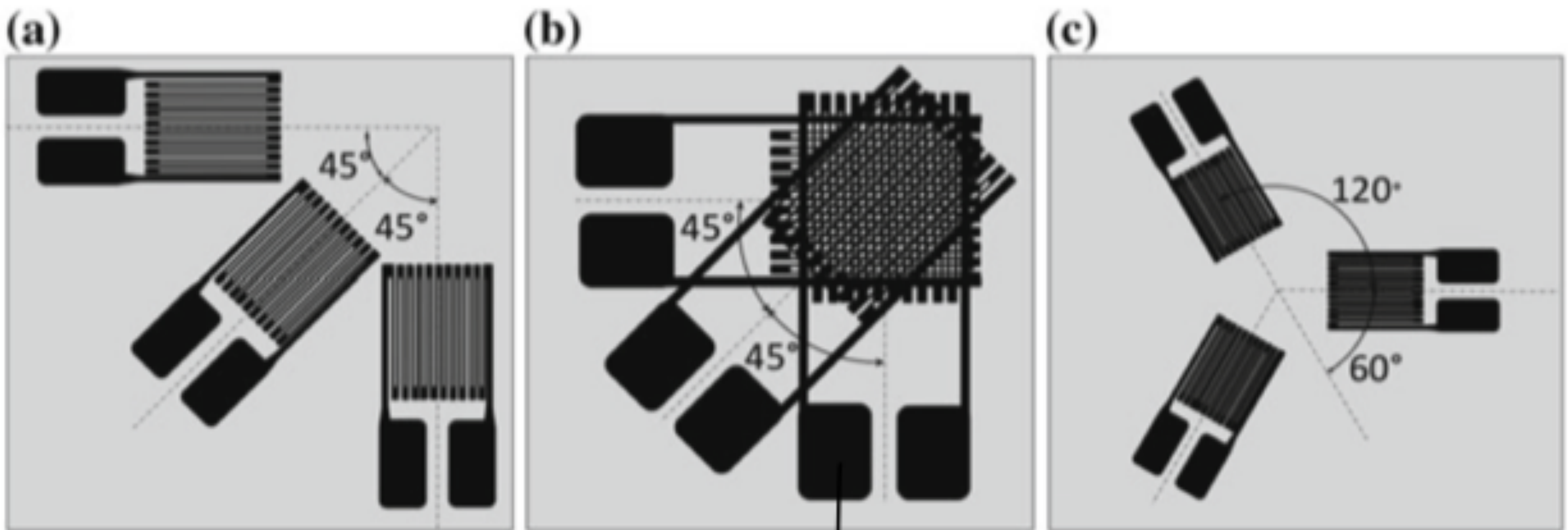
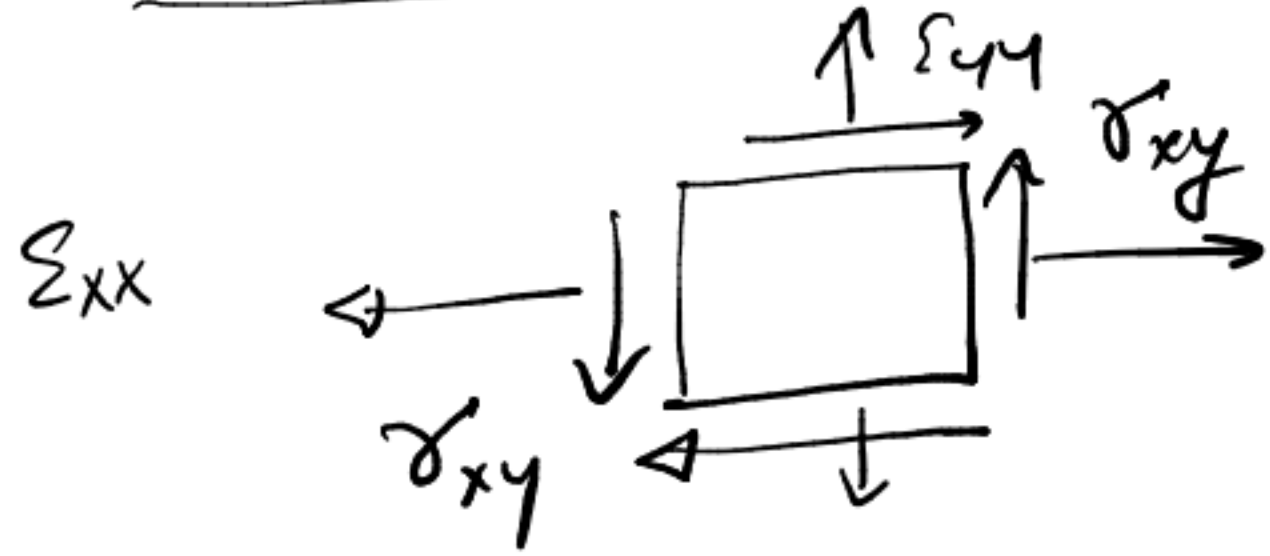


Fig. 2.7 Schematic representation of three-gage Rosettes with different layout of the strain gages at 45 and 60/120° with separated or stacked grids

more Joule heating

less Joule heating.

Strain gage Rosettes.



Rectangular Rosette.

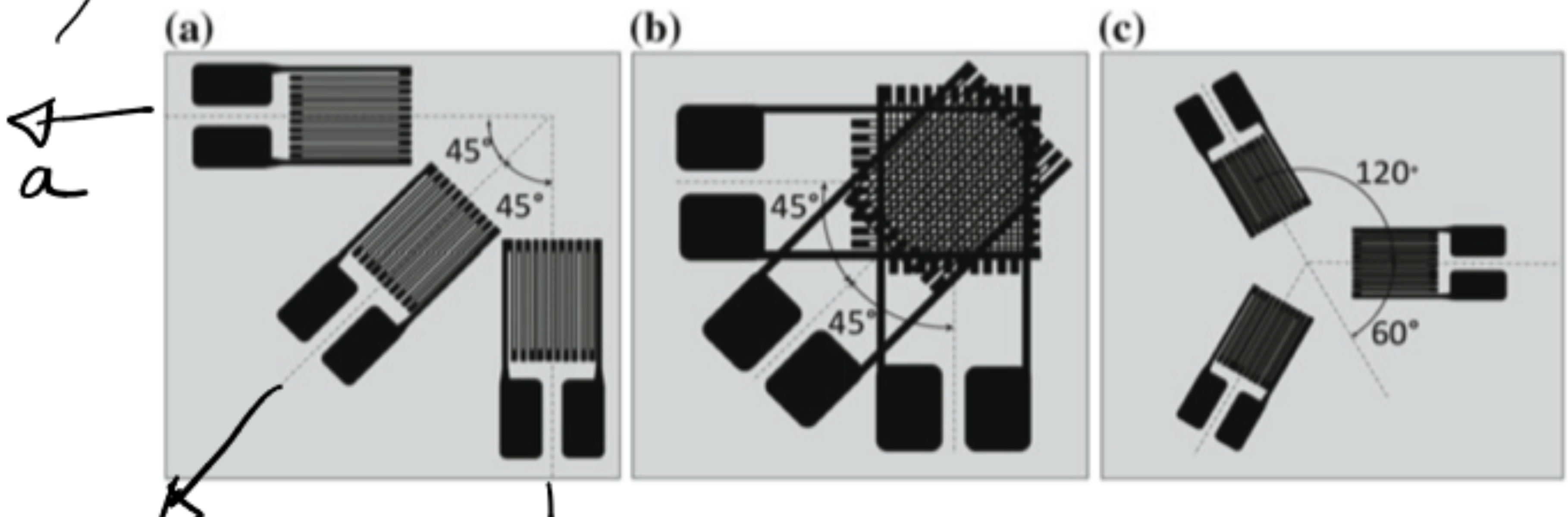


Fig. 2.7 Schematic representation of three-gage Rosettes with different layout of the strain gages at 45 and 60/120° with separated or stacked grids

$\varepsilon_a, \varepsilon_b, \varepsilon_c$ measured

Mohr's circle of strain:

$$\varepsilon_a = \frac{\varepsilon_{xx}+\varepsilon_{yy}}{2} + \frac{\varepsilon_{xx}-\varepsilon_{yy}}{2}\cos 2\theta_a + \frac{\gamma_{xy}}{2}\sin 2\theta_a.$$

$$\varepsilon_b = \text{''} + \text{''}\cos 2\theta_b + \frac{\gamma_{xy}}{2}\sin 2\theta_b$$

$$\varepsilon_c = \text{''} + \text{''}\cos 2\theta_c + \frac{\gamma_{xy}}{2}\sin 2\theta_c.$$

Rectangular rosette

$$\theta_a = 0^\circ$$
$$\theta_b = 45^\circ$$
$$\theta_c = 90^\circ$$

$\Rightarrow$

$||^{ly}$

$$\boxed{\begin{aligned} \varepsilon_{xx} &= \varepsilon_a \\ \varepsilon_{yy} &= \varepsilon_c \\ \gamma_{xy} &= 2\varepsilon_b - \varepsilon_a - \varepsilon_c \end{aligned}}$$

Principal strains:

$$\varepsilon_{1,2} = \frac{\varepsilon_{xx} + \varepsilon_{yy}}{2} \pm \sqrt{\left(\frac{\varepsilon_{xx} - \varepsilon_{yy}}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}.$$

Delta Rosette

$$\theta_a = 0^\circ$$
$$\theta_b = 120^\circ$$
$$\theta_c = 240^\circ$$

Use Mohr's circle formulae to obtain.

$$\varepsilon_{xx} = \varepsilon_a$$

$$\varepsilon_{yy} = \frac{1}{3}\left[2(\varepsilon_b + \varepsilon_c) - \varepsilon_a\right]$$

$$\gamma_{xy} = \frac{1}{\sqrt{3}}\left(\varepsilon_c - \varepsilon_b\right).$$

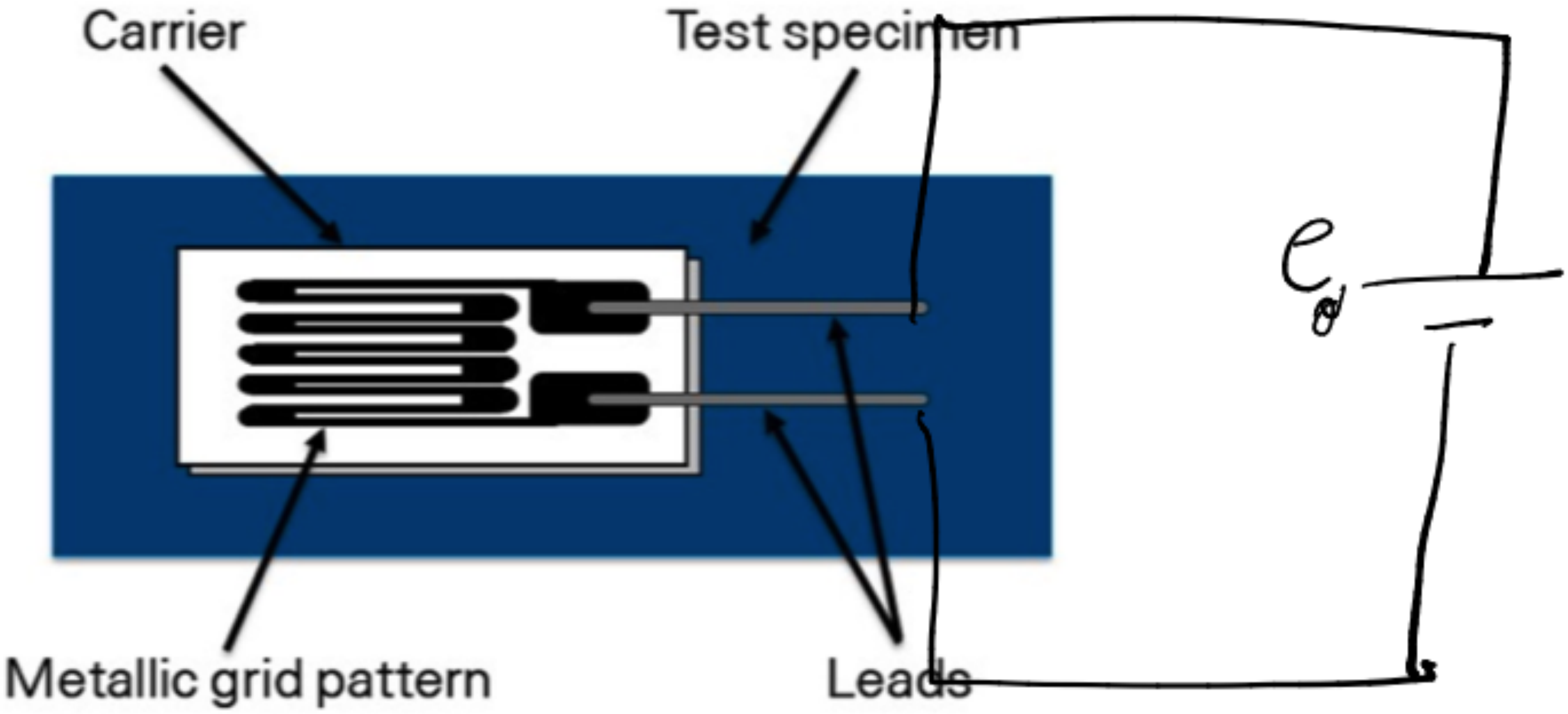
principal strains can be determined easily.

Circuitry for $\frac{\Delta R}{R}$ measurement.

Measurement of $\frac{\Delta R}{R}$ happens by measuring voltage.

$$\Delta R \sim 10^{-4}\,\Omega$$

Naive method to measure $\frac{\Delta R}{R}$ (which will not work.)



As R of the strain guage changes, only i (current) changes — Δi is too small to be picked up by an ammeter. whose range ~20mA.

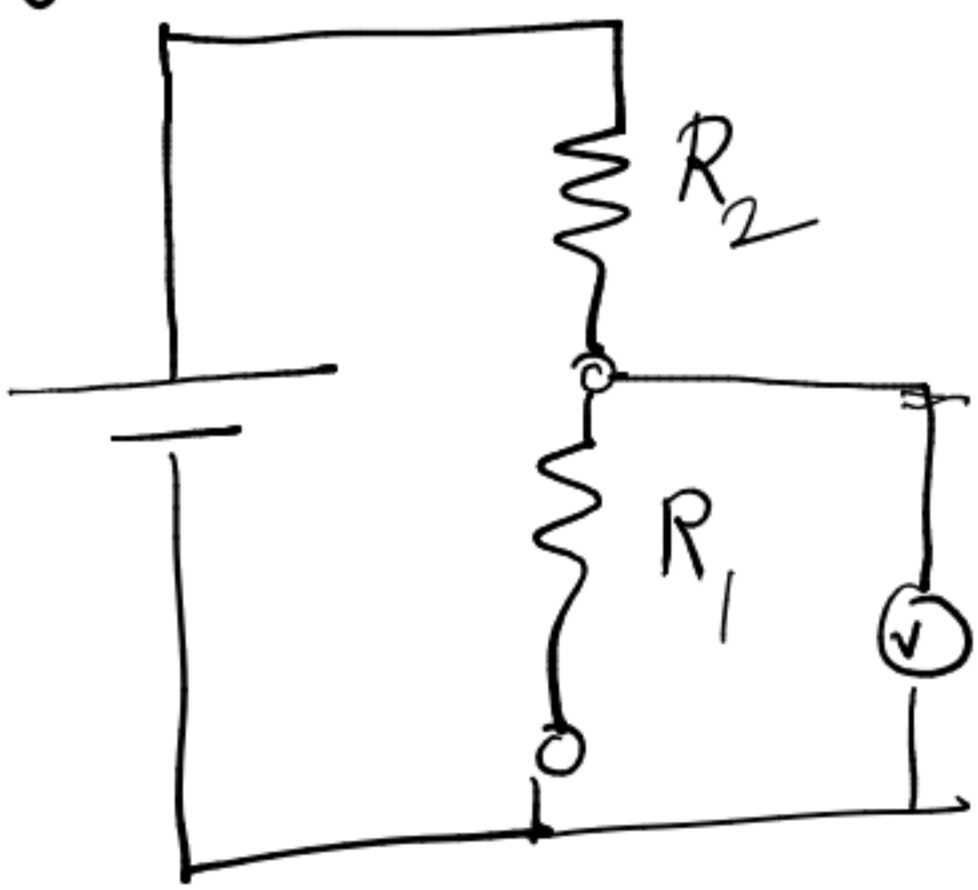
$$\frac{\text{Range of an electrical instrument}}{10^3} \approx \text{Sensitivity or least count.}$$

Second level Naive approach using a voltage divider.

e_0

$\uparrow$

emf

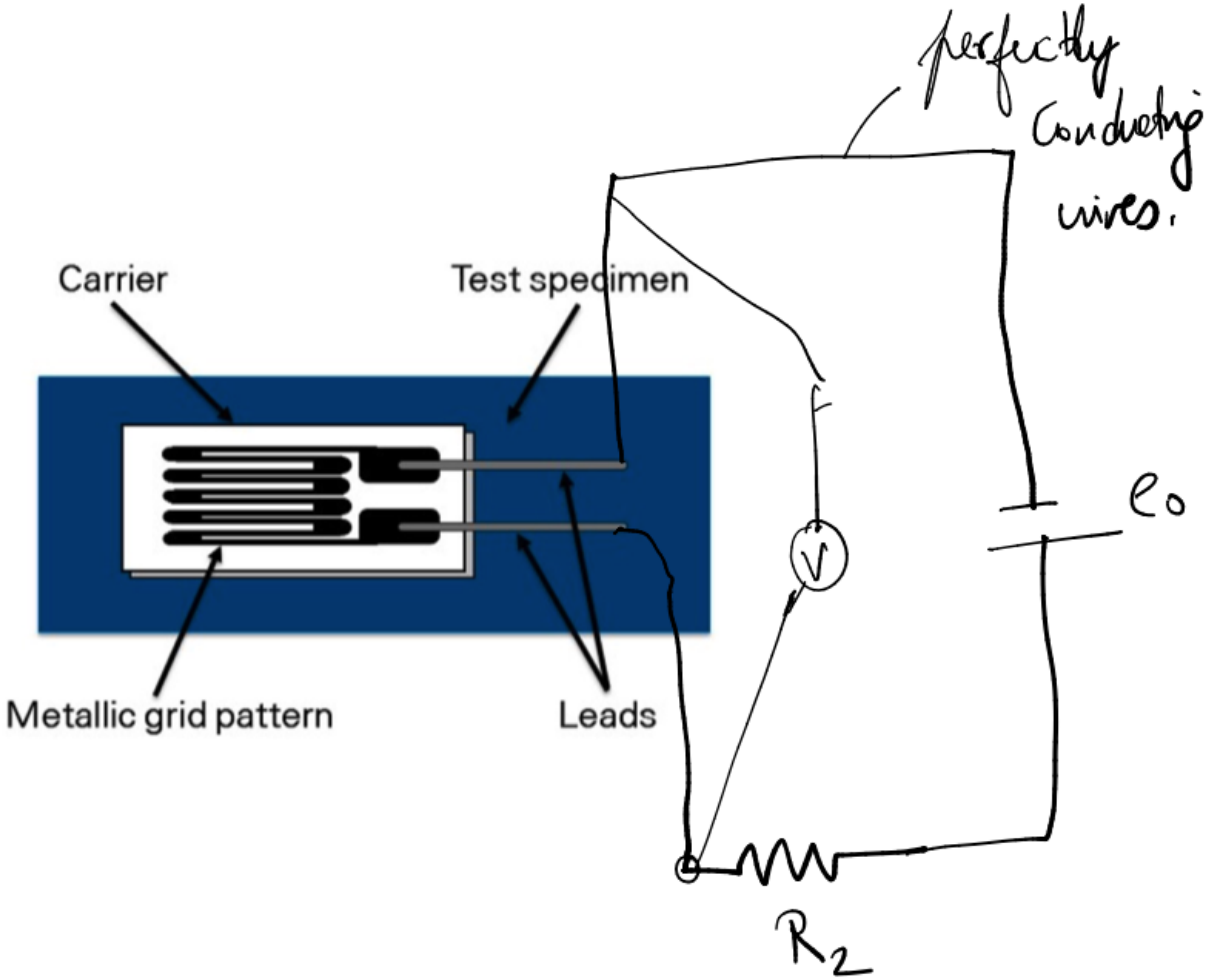


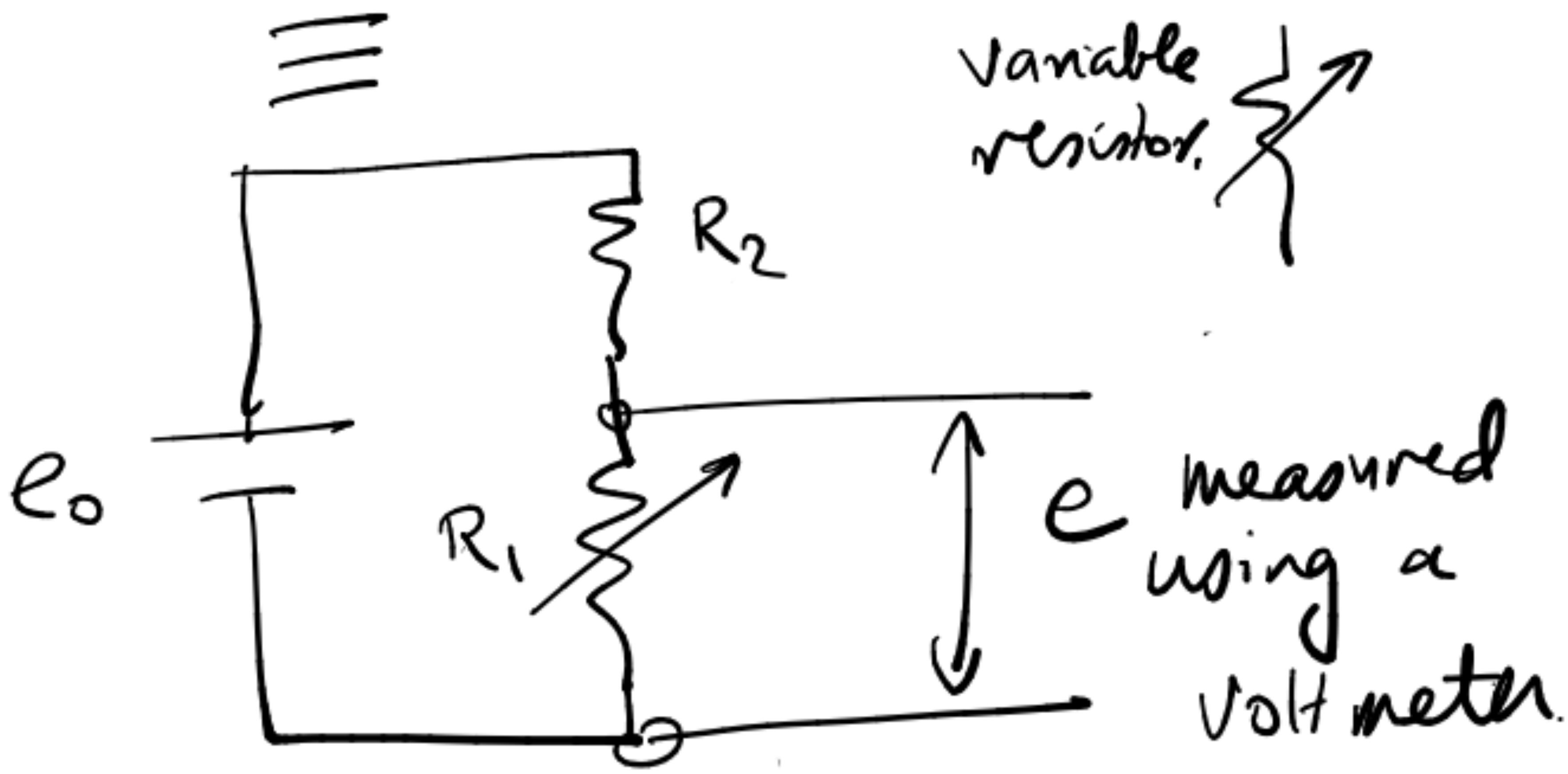
$$i = \frac{e_0}{R_1 + R_2}$$

Voltage drop across $R_2 = \frac{R_2}{R_1+R_2} \cdot e_0$

" " " $R_1 = \frac{R_1}{R_1+R_2} e_0$

Let us make R_1 the strain guage.


perfectly conducting wires.
Carrier
Test specimen
Metallic grid pattern
Leads
V
e_0
R_2


variable resistor.
R_2
e_0
R_1
e measured using a voltmeter.

R_1 = unstretched resistance of the strain guage.

ΔR_1 = change in resistance due to strain the sample.

Under zero strain,

measured by V.

$$e = e_0 \frac{R_1}{R_1 + R_2}$$

Under finite strain $R_1 \rightarrow R_1 + \Delta R_1$

$$e' = e_0 \frac{R_1 + \Delta R_1}{R_1 + \Delta R_1 + R_2}$$

$$\frac{\Delta e}{e_0} = \frac{e' - e}{e_0} = \frac{R_1 + \Delta R_1}{R_1 + \Delta R_1 + R_2} - \frac{R_1}{R_1 + R_2}$$

$$= \frac{(R_1 + \Delta R_1)(R_1 + R_2) - R_1 (R_1 + \Delta R_1 + R_2)}{(R_1 + R_2 + \Delta R_1)(R_1 + R_2)}$$

$$\frac{\Delta e}{e_0} = \frac{\Delta R_1 R_2}{(R_1+R_2)^2 + \Delta R_1 (R_1+R_2)}$$

Now ΔR_1 varies from $10^{-4}\,\Omega$ to $2.4\,\Omega$

R_1 ~ at least $120\,\Omega$

Select R_2 ~ " " "

$$\Delta R_1 << R_1 + R_2$$

$$\frac{\Delta e}{e_0} = \frac{\Delta R_1 R_2}{(R_1+R_2)^2}$$

$S\,\varepsilon$

$$= \frac{R_1 R_2}{(R_1+R_2)^2} \cdot \frac{\Delta R_1}{R_1}$$

$$\frac{\Delta e}{e_0} = \frac{R_1 R_2}{(R_1+R_2)^2} \cdot S \cdot \varepsilon.$$

Often, R_2 is chosen equal to R_1.

measured → Δe

known → e_0

$$\frac{\Delta e}{e_0} = \frac{S\,\varepsilon}{4}$$

known from calibration

The voltmeter should be able to measure e_0.

Sensitivity of such a voltmeter ~ $e_0/1000$.

If Δe (change in voltage because of change in strain $< e_0/1000$), our measurement strategy will fail.