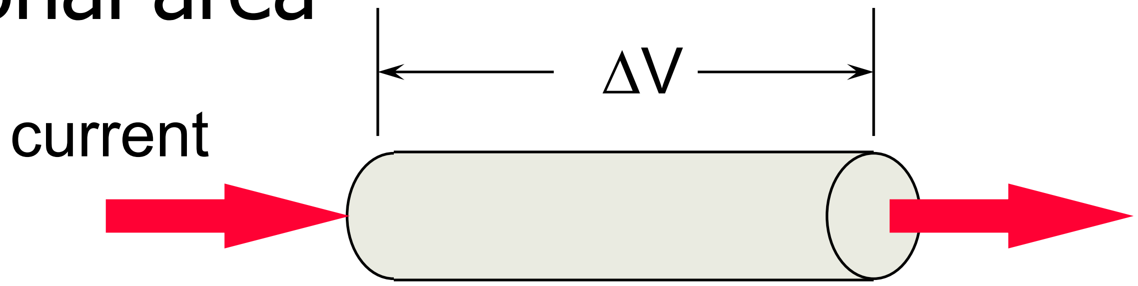
# Chapter 8
# Strain Gages

# Resistance

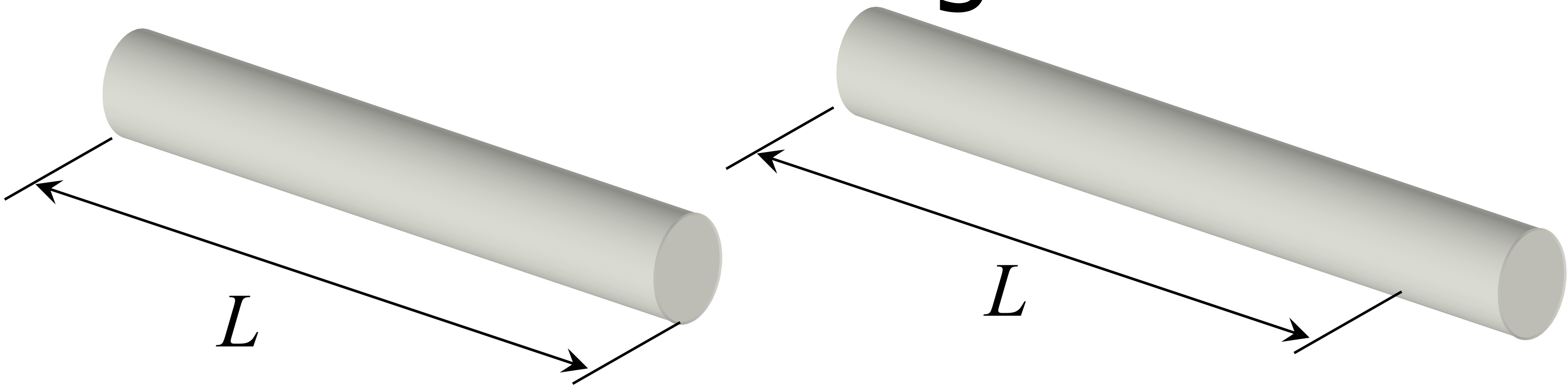
- The electrical resistance of most materials is a function of material properties and cross-sectional area




larger cross-section $\Rightarrow$

$$R =$$

# Strain Gages

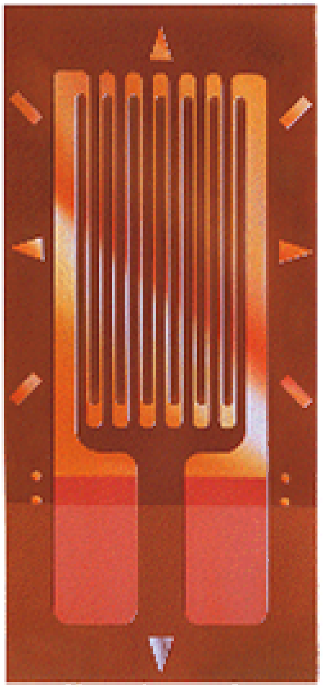



- strain gages convert ______,
- to a change in _________

# Foil Element Strain Gage

- the ratio between strain and resistance is the ________________, F

$$F = \frac{\Delta R / R}{\Delta L / L} = \frac{\Delta R / R}{\varepsilon} \Rightarrow \frac{\Delta R}{R} = F\varepsilon$$



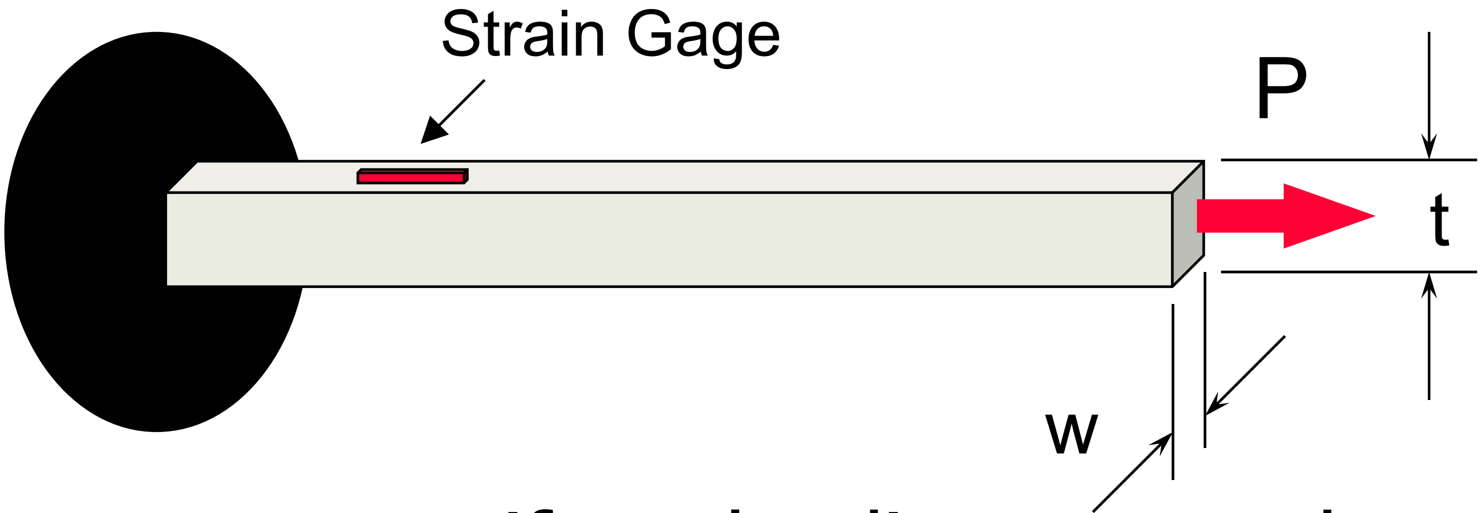
- for foil gages, F~2
- for semiconductor gages, F~ 25 to 50

# Strain Gage Mounting

**Important Note:**

- strain gages convert the strain seen by the gage into a resistance change
- the strain gage installer must ensure that the gage experiences the desired strain by careful installation!
  - usually mount gages by gluing ("SuperGlue") or welding to structure

# One Gage - Uniform Member in Pure Tension




- if we assume uniform loading across the width of the beam,

$$\sigma =$$

# One Gage - Pure Tension

- we have _______ stress, so

$$\sigma =$$

  - where E = modulus of elasticity,
    - $E_{steel}$ ~ ______________________
    - $E_{alum}$ ~ ______________________

# One Gage - Pure Tension

- solving for strain, $\varepsilon =$

$$\frac{\Delta R}{R} = F\varepsilon \Rightarrow$$

  - Find ΔR if
    - P = 3200 lb
    - F = 2.1, R = 120Ω
    - w = 1.0 inch, t = 0.25 inch
    - material is steel

# One Gage - Pure Tension

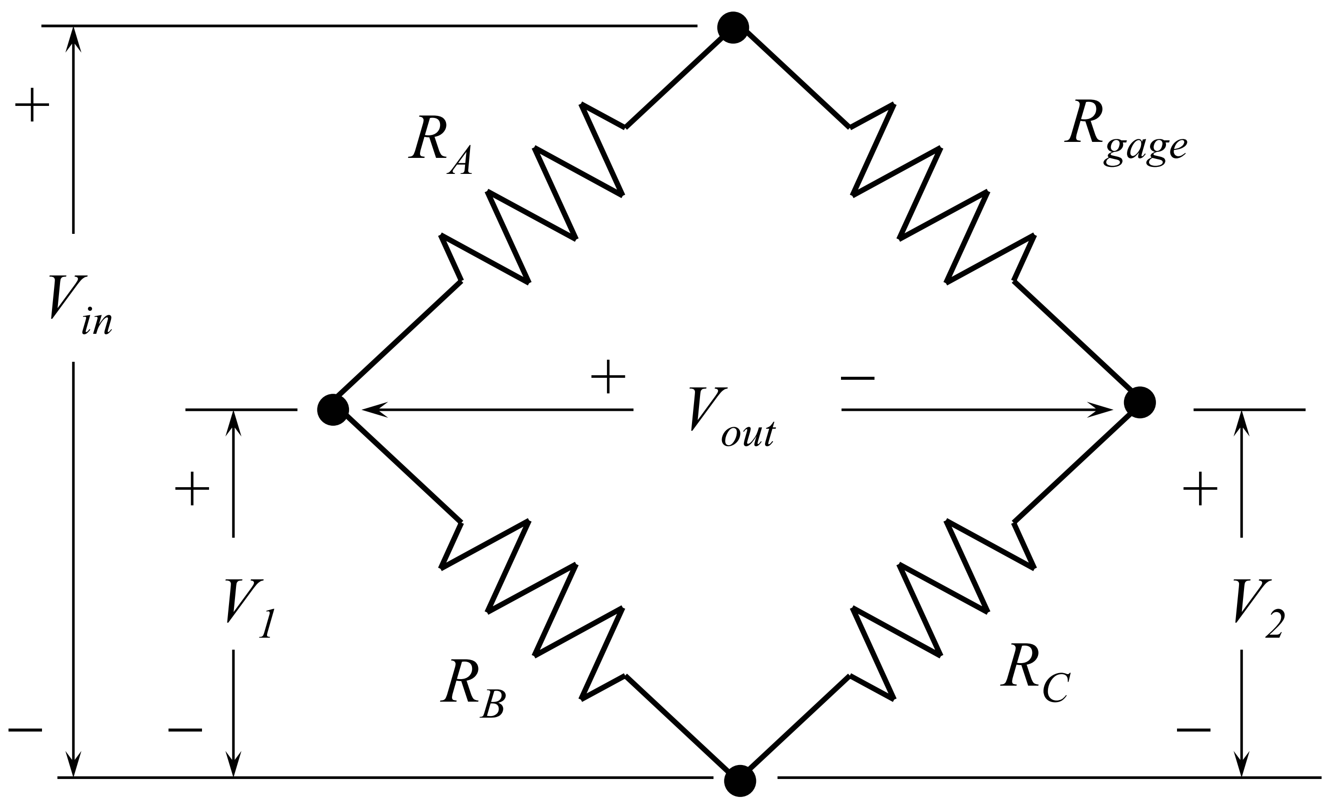
- small change in resistance, ____________
- would require a ***very*** accurate DMM to measure
  - this was a 3200 lb load!
- totally impractical to measure resistance change directly for “small” loads on the order of 100 lbs

# Wheatstone Bridges

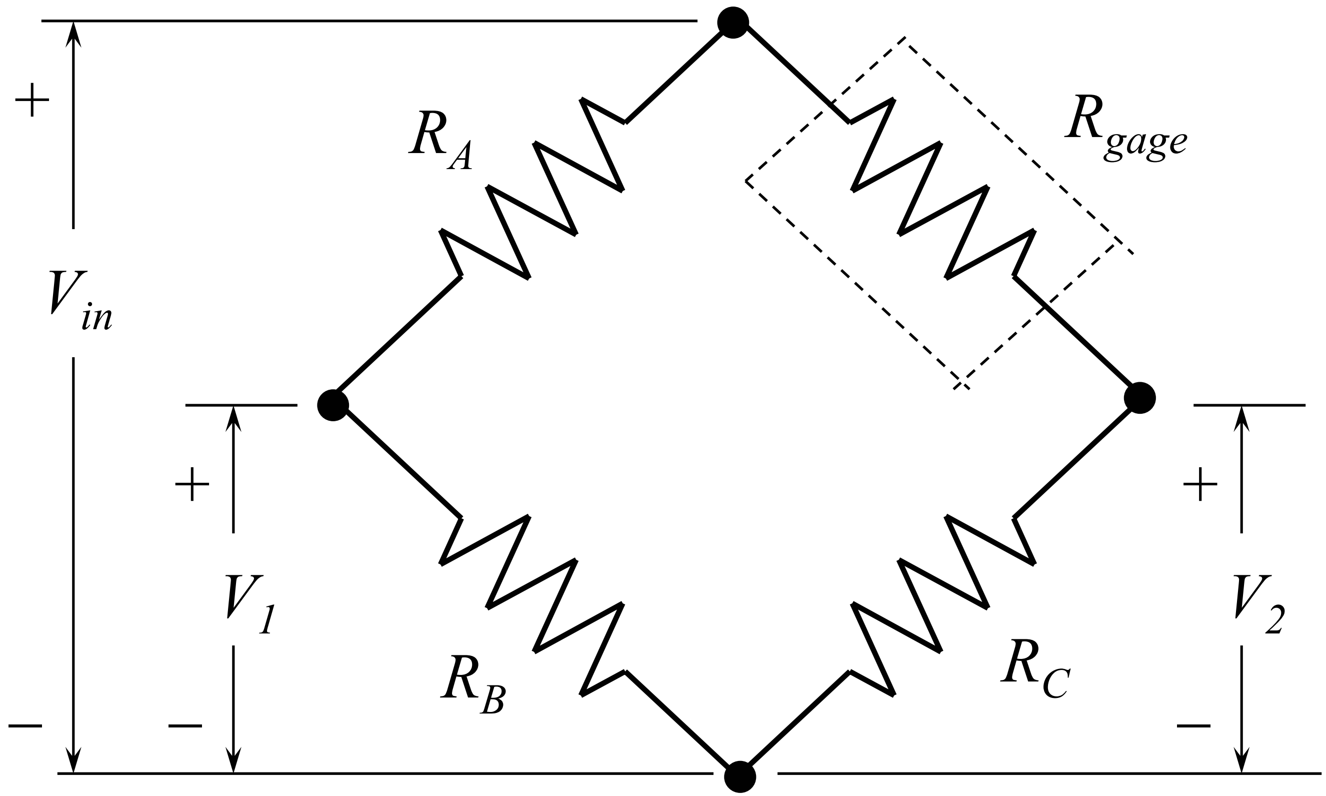
Used to measure the small resistance changes created by strain gages

# "Quarter" Bridge Circuit

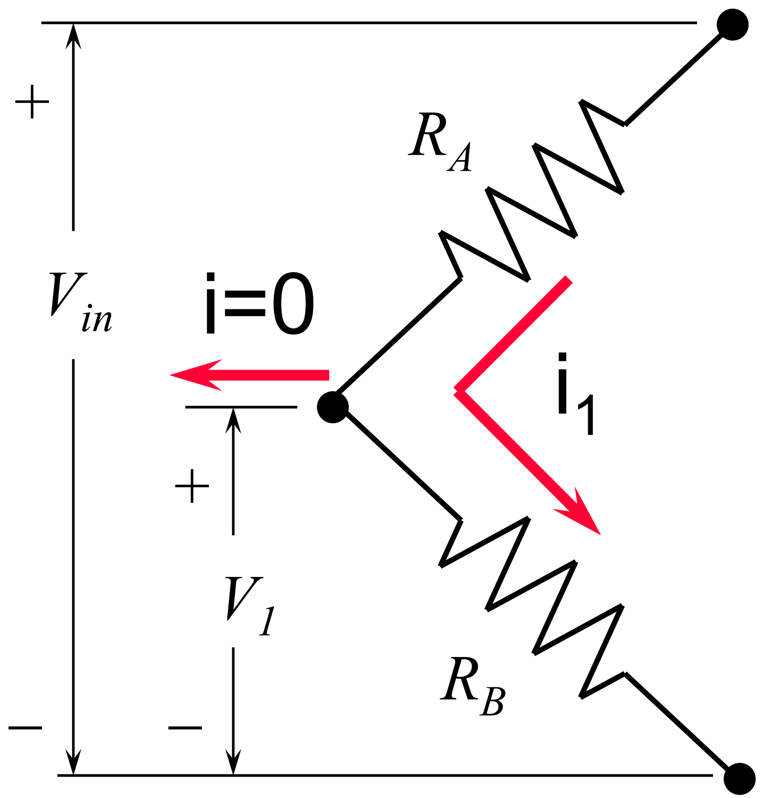
1 of 4 "legs" of the Wheatstone Bridge is a strain gage



# "Quarter" Bridge Circuit



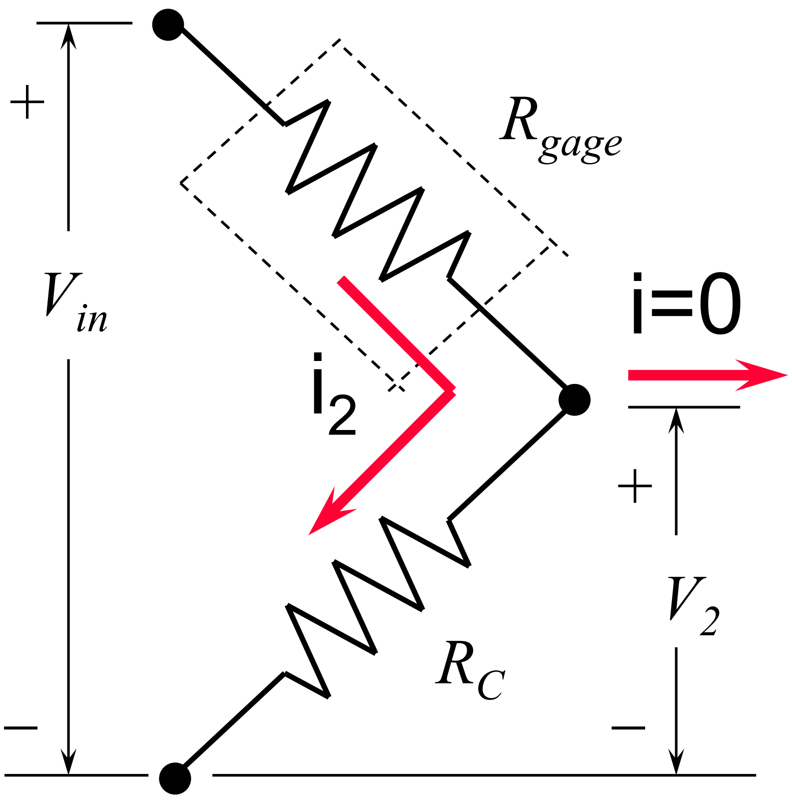
# Left Side Voltage Divider




$V_1 =$

# Right Side Voltage Divider

$$V_2 =$$



# Quarter Bridge Analysis

- normally make all fixed resistors equal,

- gage output is “nominal” resistance + “delta” (change) resistance,

$$R_{gage} =$$

# Quarter Bridge Analysis

- substituting resistance values,

$$V_1 =$$

$$V_2 =$$

# Quarter Bridge Analysis

- defining the output voltage,

$$V_{out} = V_1 - V_2 =$$

# Quarter Bridge Analysis

- recall that the change in the gage resistance is very small,

$$\frac{2\Delta R}{R} << 4 \Rightarrow \quad 4 + \frac{2\Delta R}{R} \approx$$

$$\Rightarrow V_{out} = \frac{\left(\frac{\Delta R}{R}\right)}{\left(4 + \frac{2\Delta R}{R}\right)} V_{in} \approx$$

# Quarter Bridge Analysis (cont.)

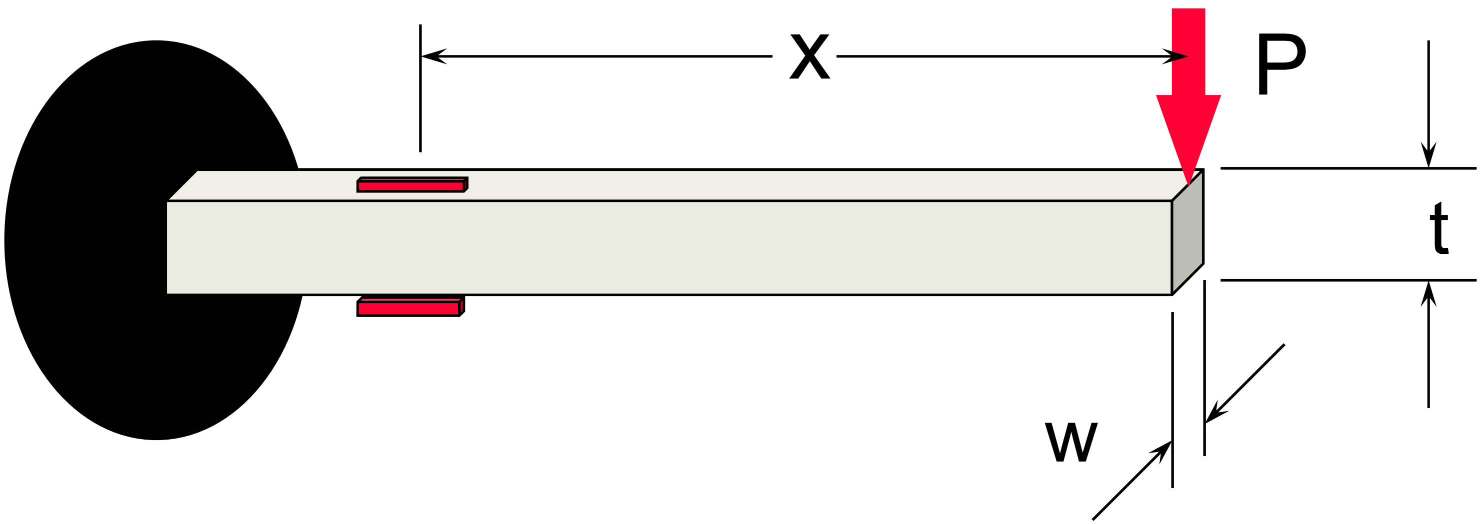
- P = 3200 lb
- F = 2.1, R = 120Ω
- w = 1.0 inch, t = 0.25 inch
- material is steel
- $V_{in}$ = 5 volts

→ ΔR ~ 0.11Ω

$$\Rightarrow \frac{\Delta R}{R} =$$

$$V_{out} = \frac{1}{4}\left(\frac{\Delta R}{R}\right)V_{in} \Rightarrow \qquad V_{out} =$$

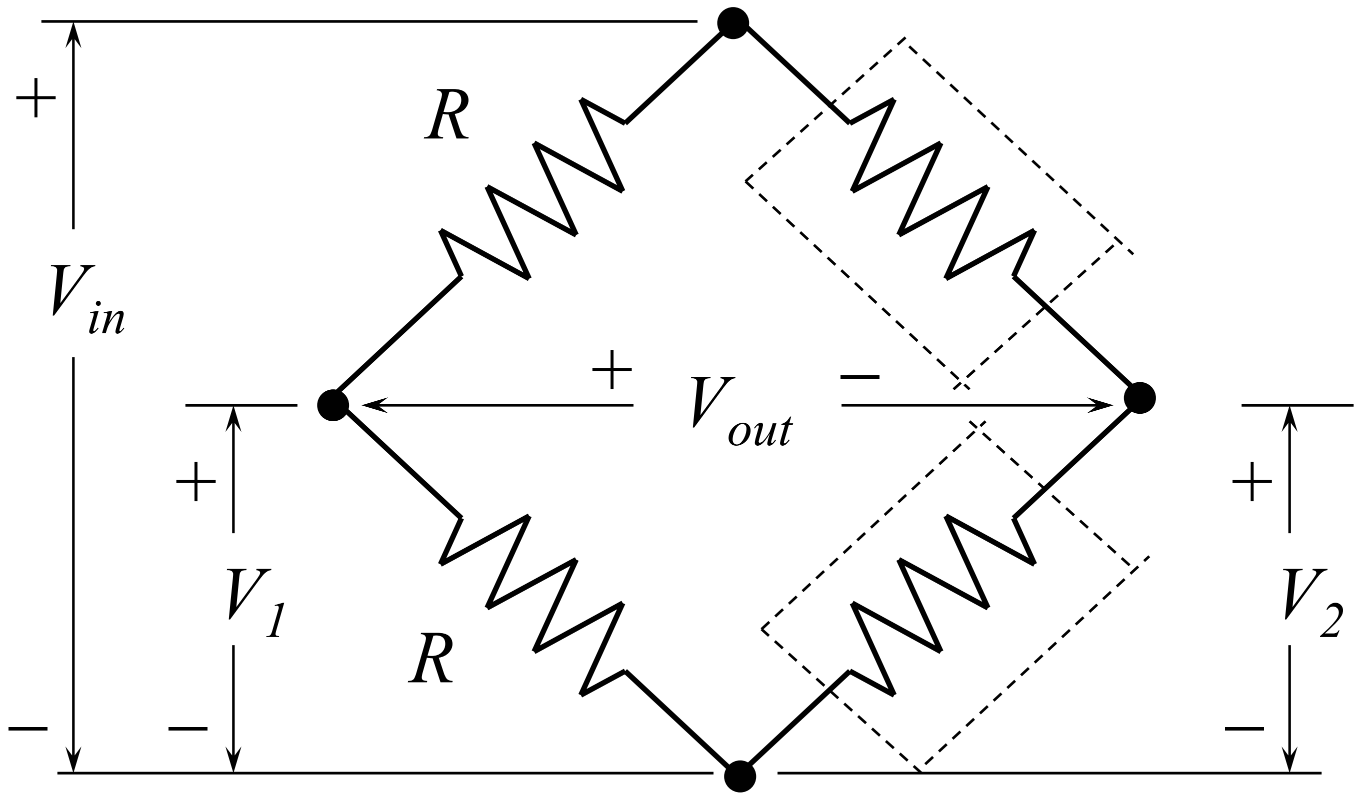
# Two Gages - Cantilever Beam




- If mounted correctly, the 2 gages "see" the same strain magnitude, where
  - one gage in tension ________ and
  - one gage in compression ________

# “Half” Bridge Circuit

2 of 4 “legs” of the Wheatstone Bridge are strain gages



# Half Bridge Analysis

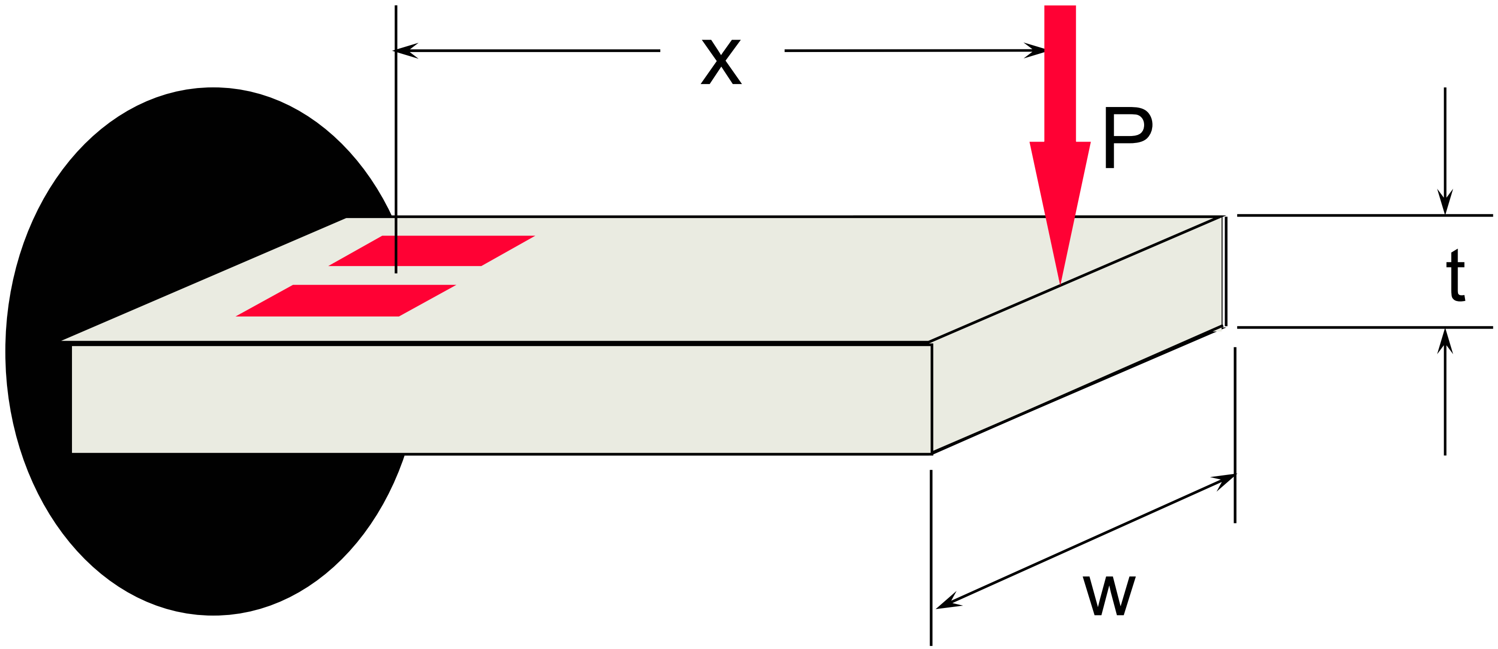
- substituting resistance values,

$$V_1 = \frac{R}{R+R}V_{in}, \quad V_2 =$$

$$V_{out} = V_1 - V_2 =$$

$$V_{out} =$$

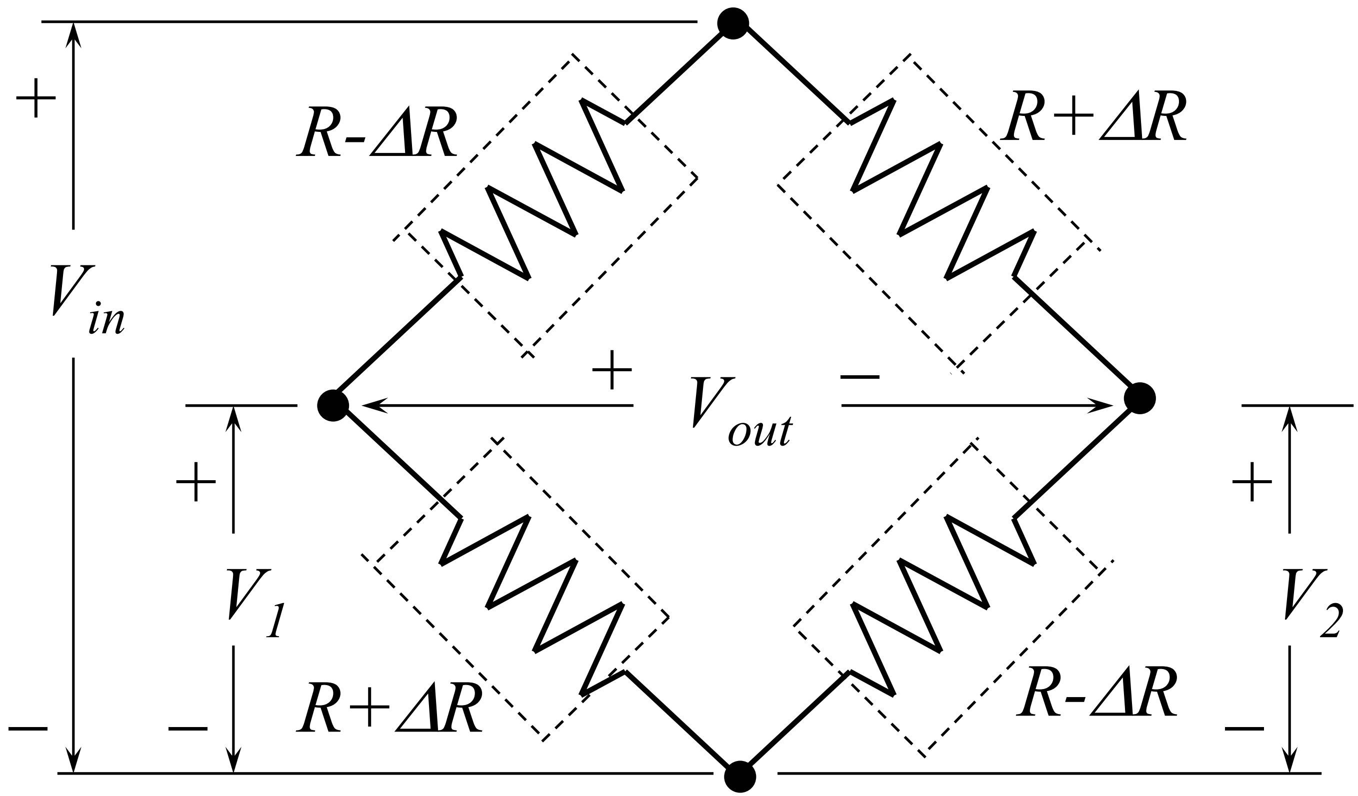
# Four Gages - Cantilever Beam




- two gages on top in tension ($R+\Delta R$) and
- two gages on bottom in compression ($R-\Delta R$)

# “Full” Bridge Circuit

All 4 “legs” of the Wheatstone Bridge are strain gages



# “Full” Bridge - Pure Bending

- gages of opposite strain in adjacent legs of bridge,

$$\frac{V_{out}}{V_{in}} =$$

- Find σ, ε, ΔR, and $V_{out}$ if
  - P = 50 lb, F = 2.0, R = 350Ω
  - w = 1.0 inch, t = 0.25 inch, x = 6.0 inch
  - material is aluminum ($E_{AL}$ ~ $10.5 \times 10^6$ psi )
  - $V_{in}$ = 12.1 volts

# 360 Pre-Requisite Knowledge

**Formulas from Strength of Materials:**

Uniaxial Stress/Strain : $\sigma = E\varepsilon$

"Hoop" Stress in Thin Wall Pressure Vessel (Uniaxial) : $\sigma = \dfrac{Pd}{2t}$

Area Moment of Inertia – Rectangular Cross-Section : $I = \dfrac{wt^3}{12}$

Uniaxial Stress - Pure Tension : $\sigma = \dfrac{P}{A}$

Uniaxial Stress - Pure Bending : $\sigma = \dfrac{My}{I}$

Area Moment of Inertia – Round Cross-Section: $I = \dfrac{\pi d^4}{64} = \dfrac{\pi r^4}{4}$