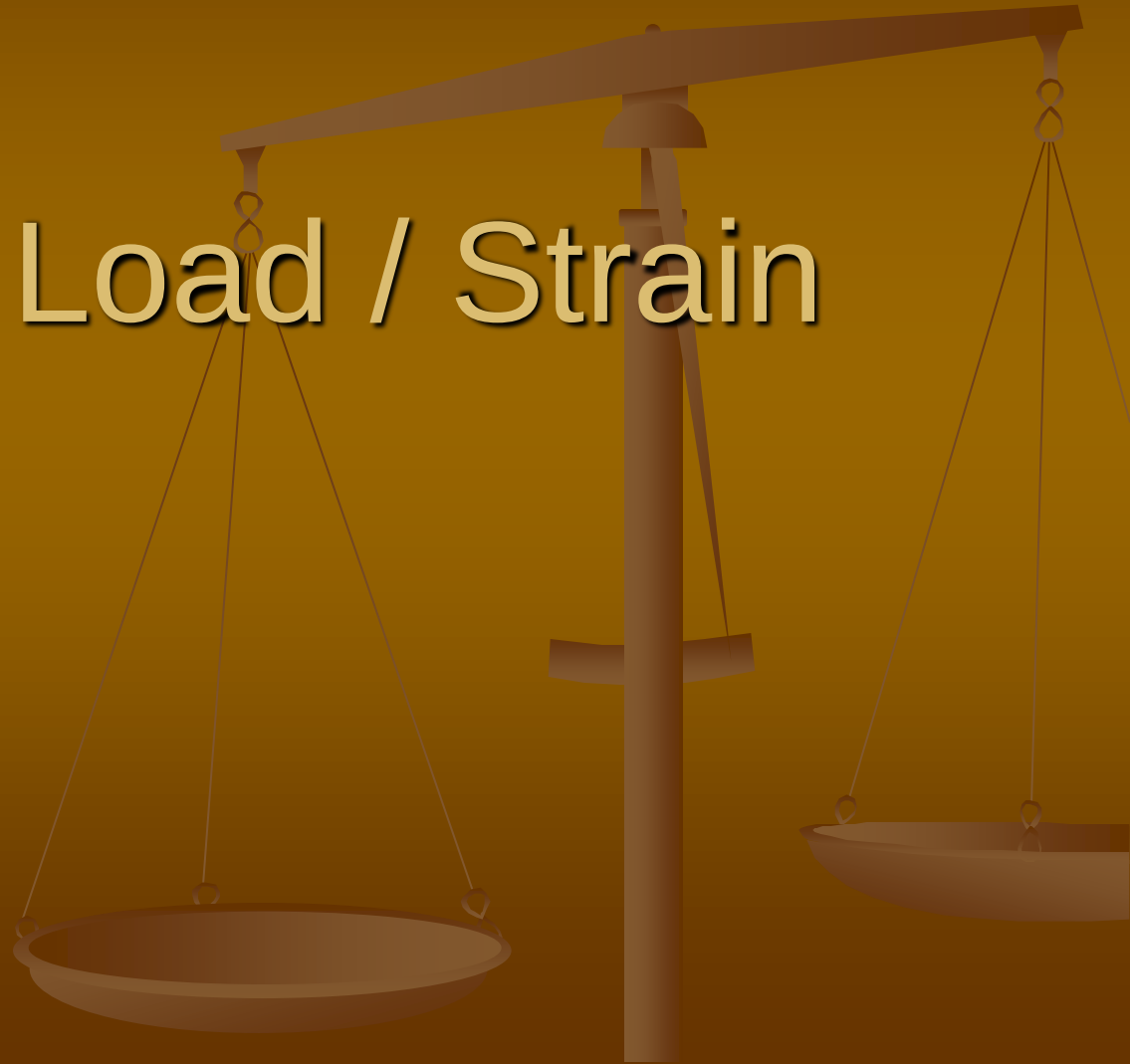
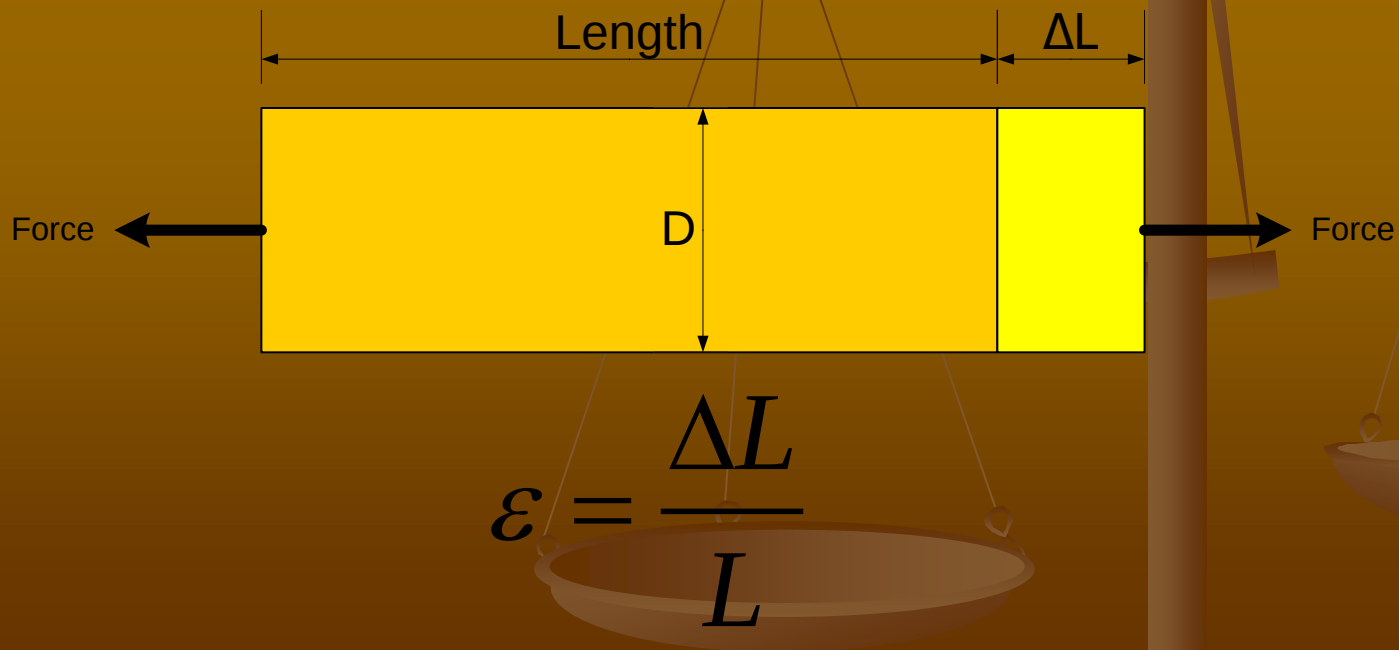


Force / Load / Strain



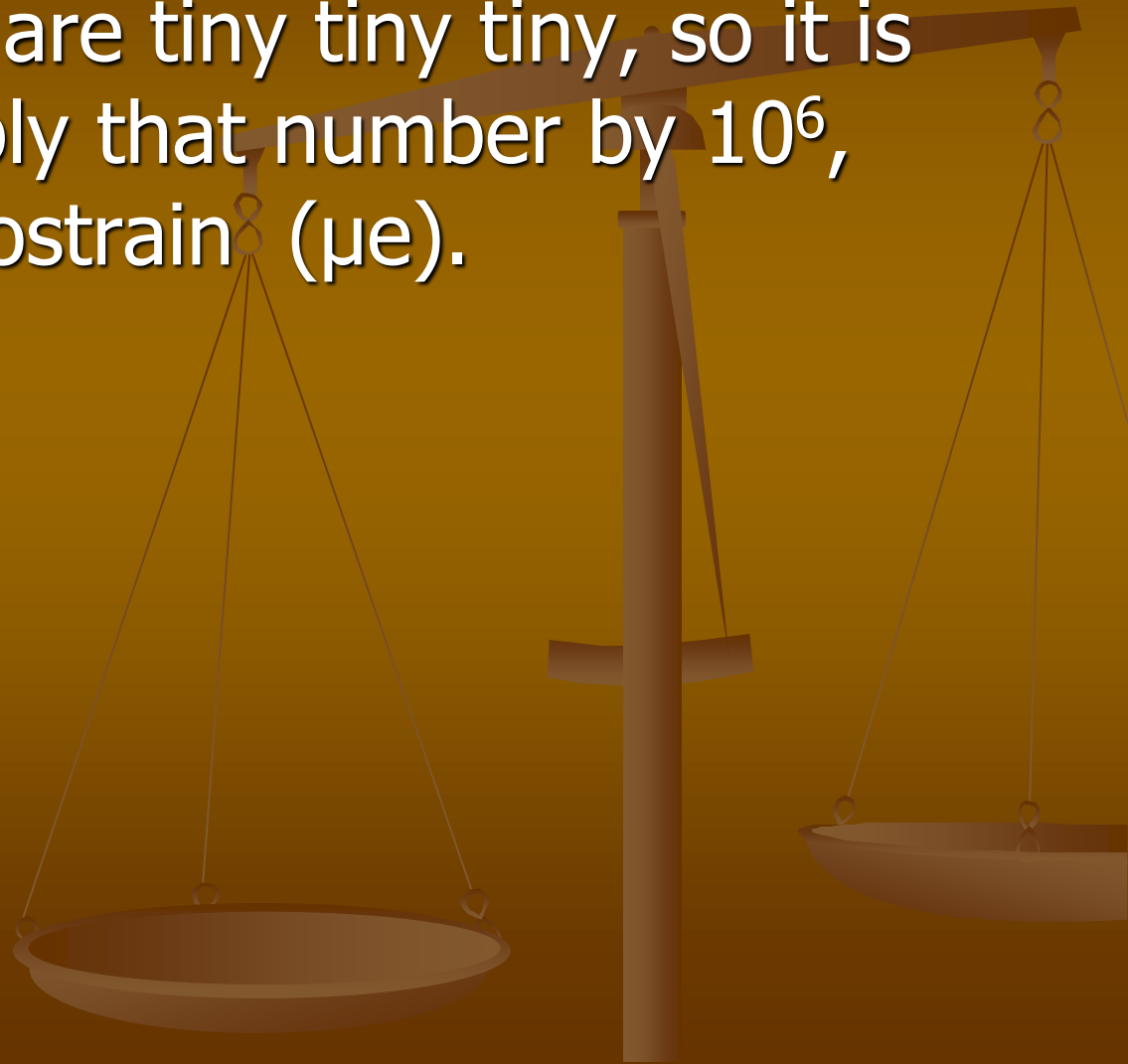
Strain

- Definition: Strain is the amount of deformation of a body due to an applied force. More specifically, strain ($\mathcal{E}$) is defined as the fractional change in length



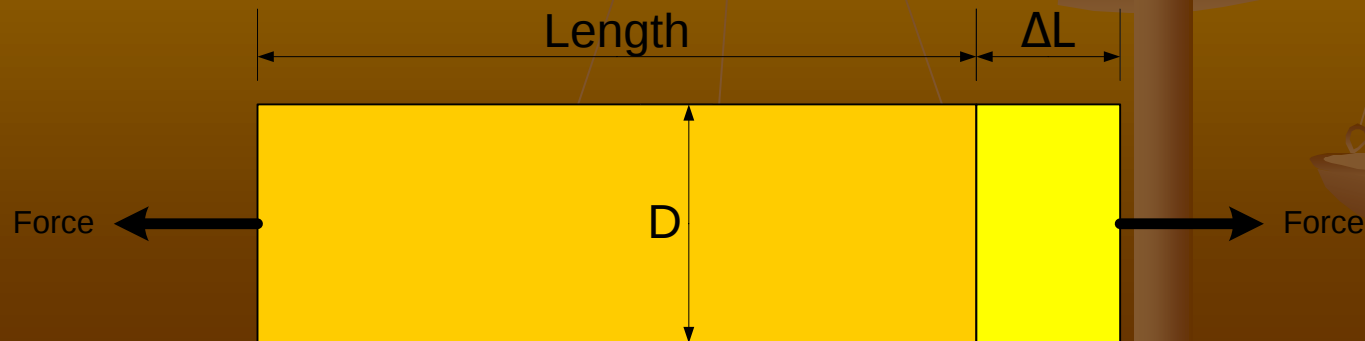
Microstrain

- Strain numbers are tiny tiny tiny, so it is typical to multiply that number by 10^6 , defined as microstrain ($\mu\epsilon$).



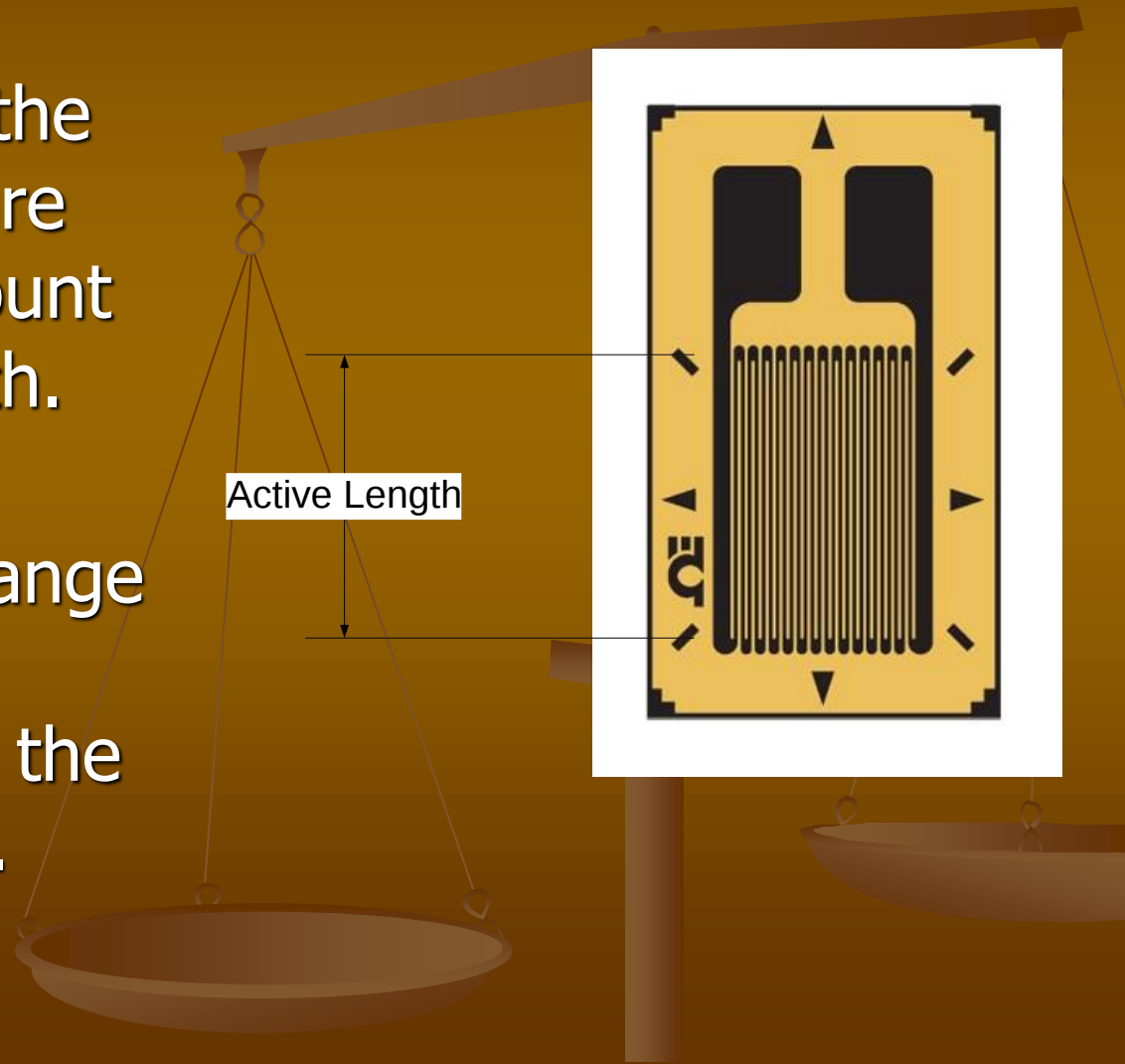
Poissons ratio

When a bar is strained with a uniaxial force, a phenomenon known as Poisson Strain causes the girth of the bar, D , to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio.



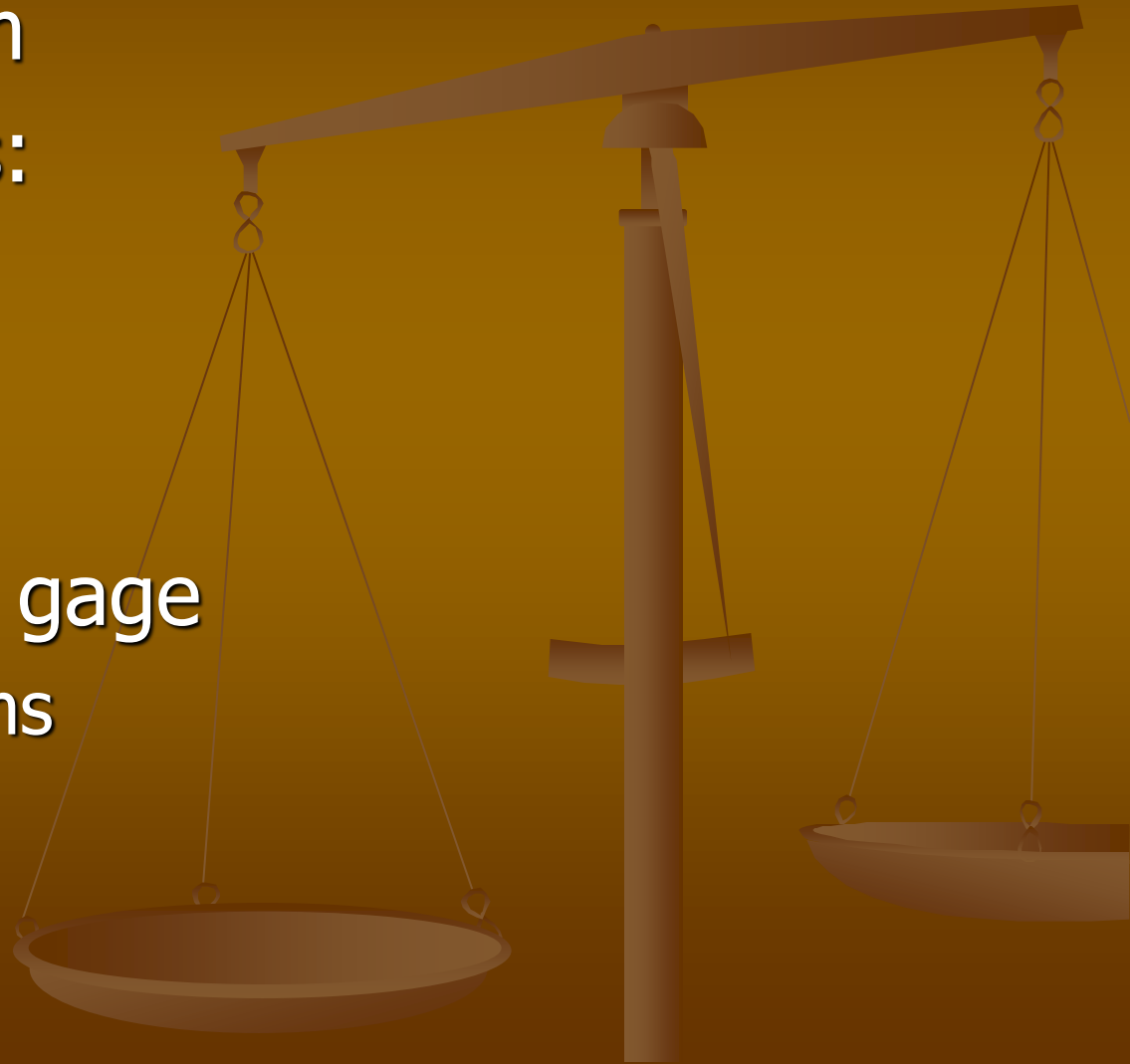
The Strain Gauge

- A small resistance element glued to the material to measure the miniscule amount of change in length.
- The active area elongates with change in length of the material changing the resistance slightly.



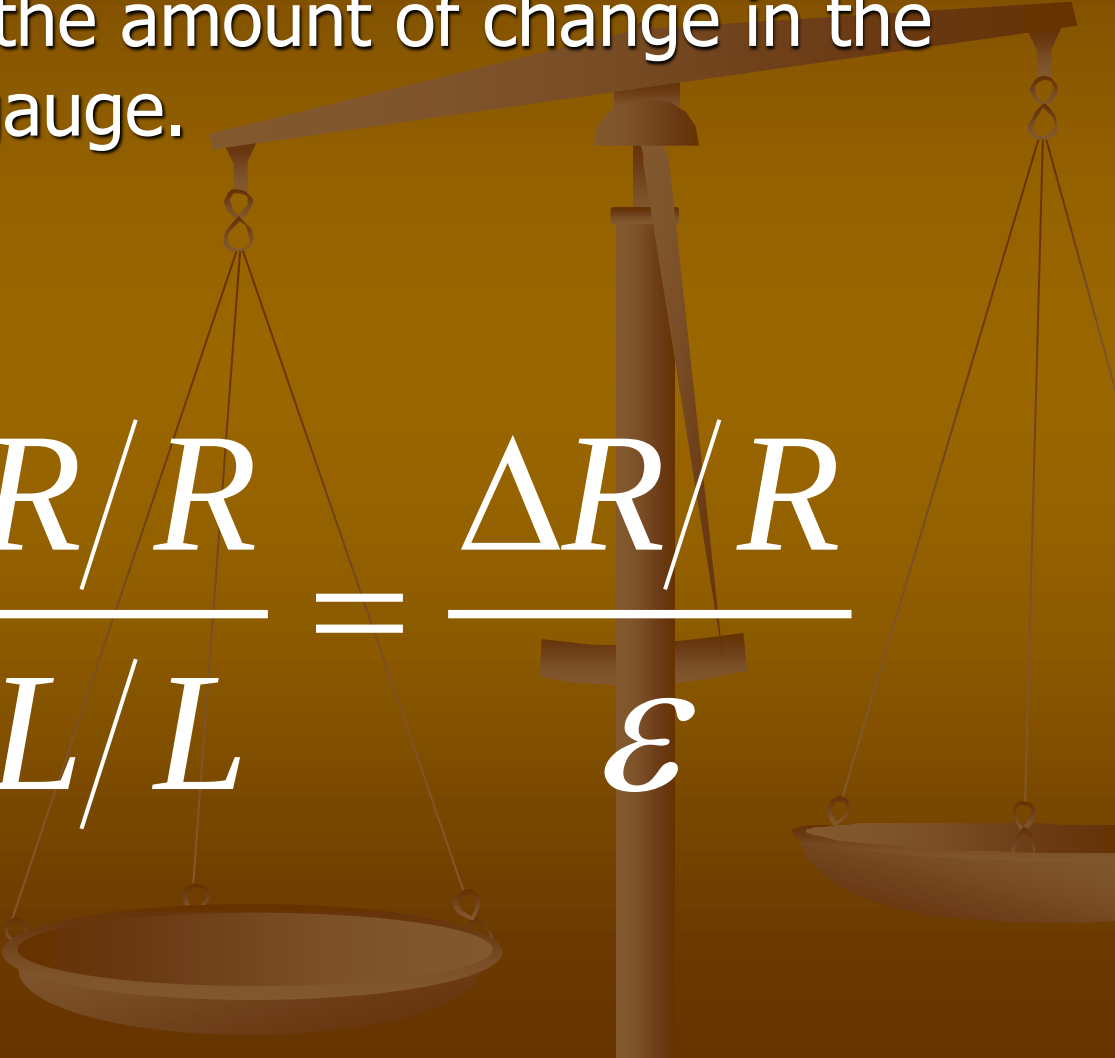
Gauge resistance

- Typical 350 ohm
- Common values:
 - 120 ohms
 - 1000 ohms
 - 240 ohms
- Semi-conductor gage
 - Up to 3500 ohms



Gauge Factor

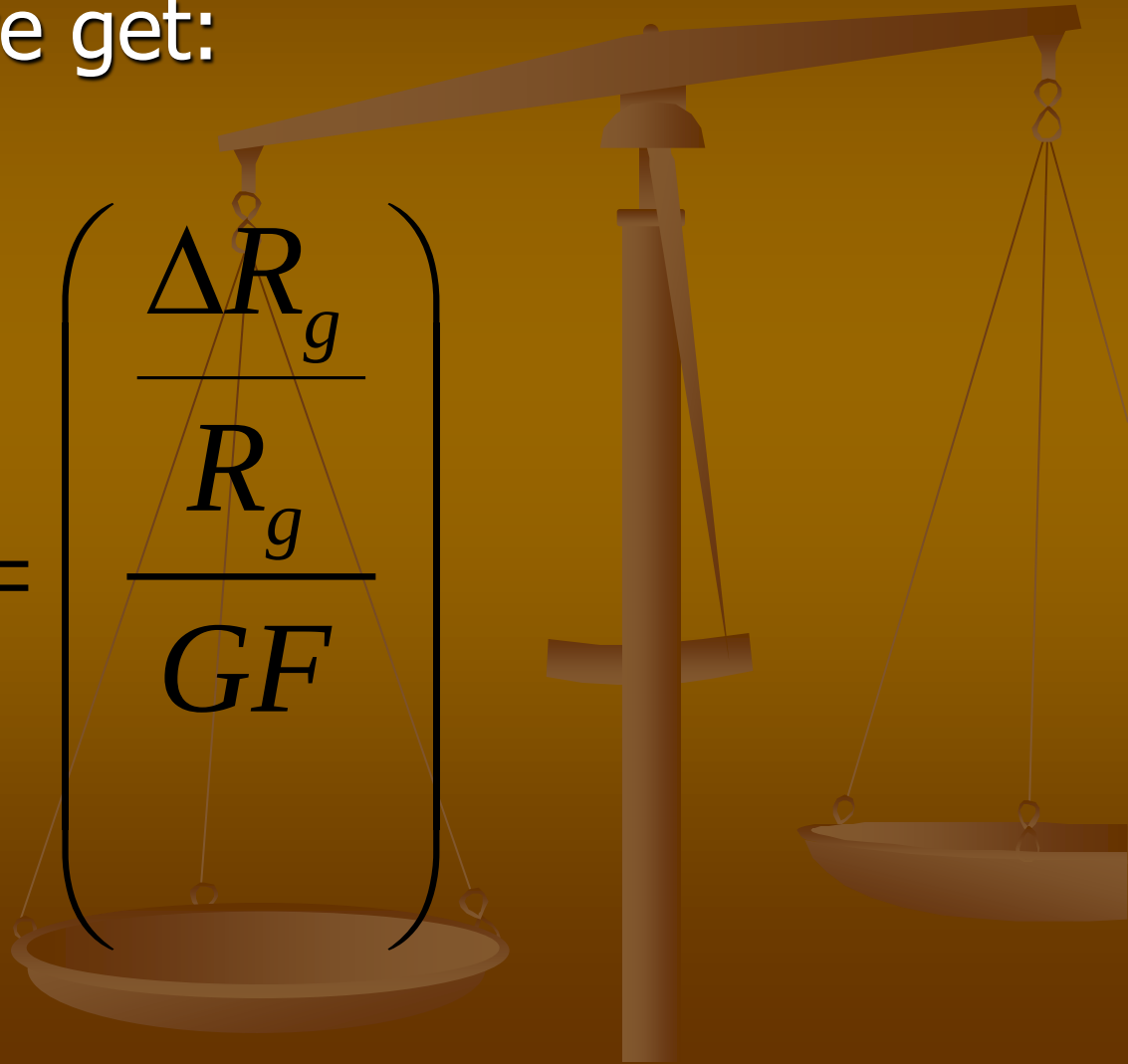
- The calibration of the amount of change in the resistance of the gauge.

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$


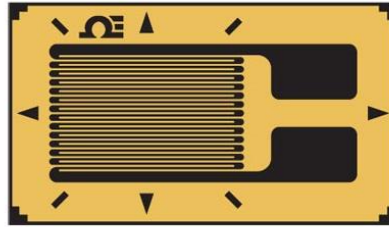
Gauge factor

- Reducing this we get:

$$\text{Strain} = \left(\frac{\frac{\Delta R_g}{R_g}}{GF} \right)$$

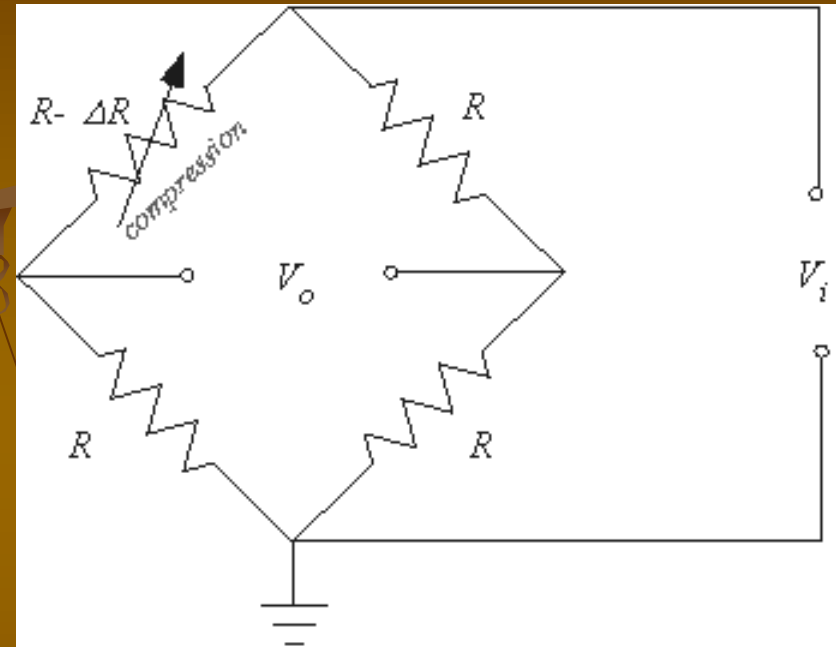


Single gauge (Quarter bridge)



Quarter bridge

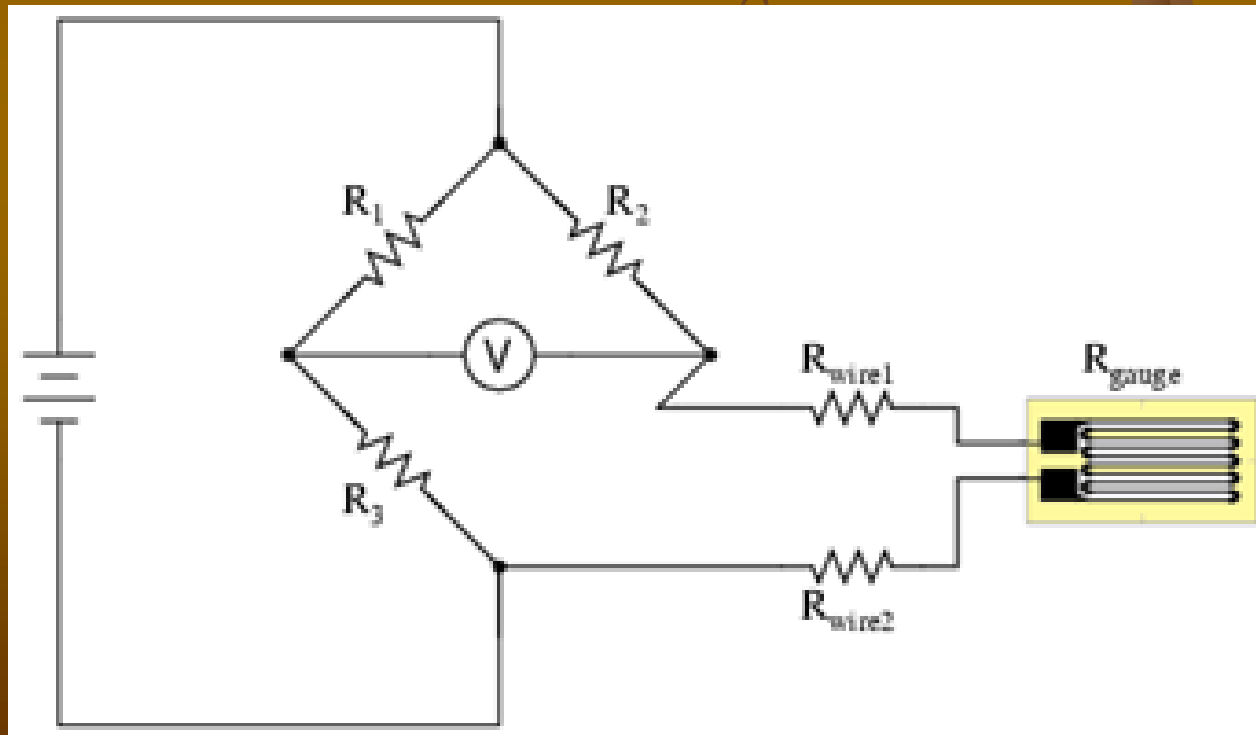
- Assume three balance resistors the same value as the gauge resistance.



$$\begin{aligned} V_o &= \left(\frac{R_3}{R_1 + R_3} - \frac{R_4}{R_2 + R_4} \right) V_i = \left(\frac{R}{(R - \Delta R) + R} - \frac{R}{R + R} \right) V_i \\ &= \left(\frac{R}{2R - \Delta R} - \frac{1}{2} \right) V_i = \left(\frac{2R - (2R - \Delta R)}{2(2R - \Delta R)} \right) V_i \\ &= \left(\frac{\Delta R / R}{2(2 - \Delta R / R)} \right) V_i \\ &\approx \frac{\Delta R}{4R} V_i. \end{aligned}$$

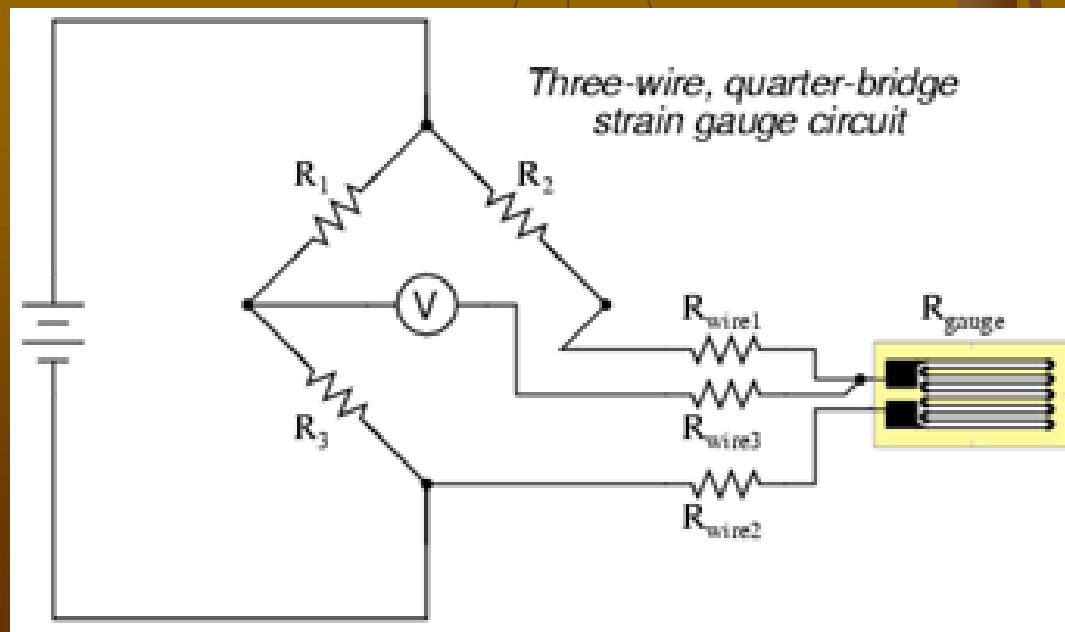
Quarter bridge wiring

- Lead wires add to the gauge resistance.



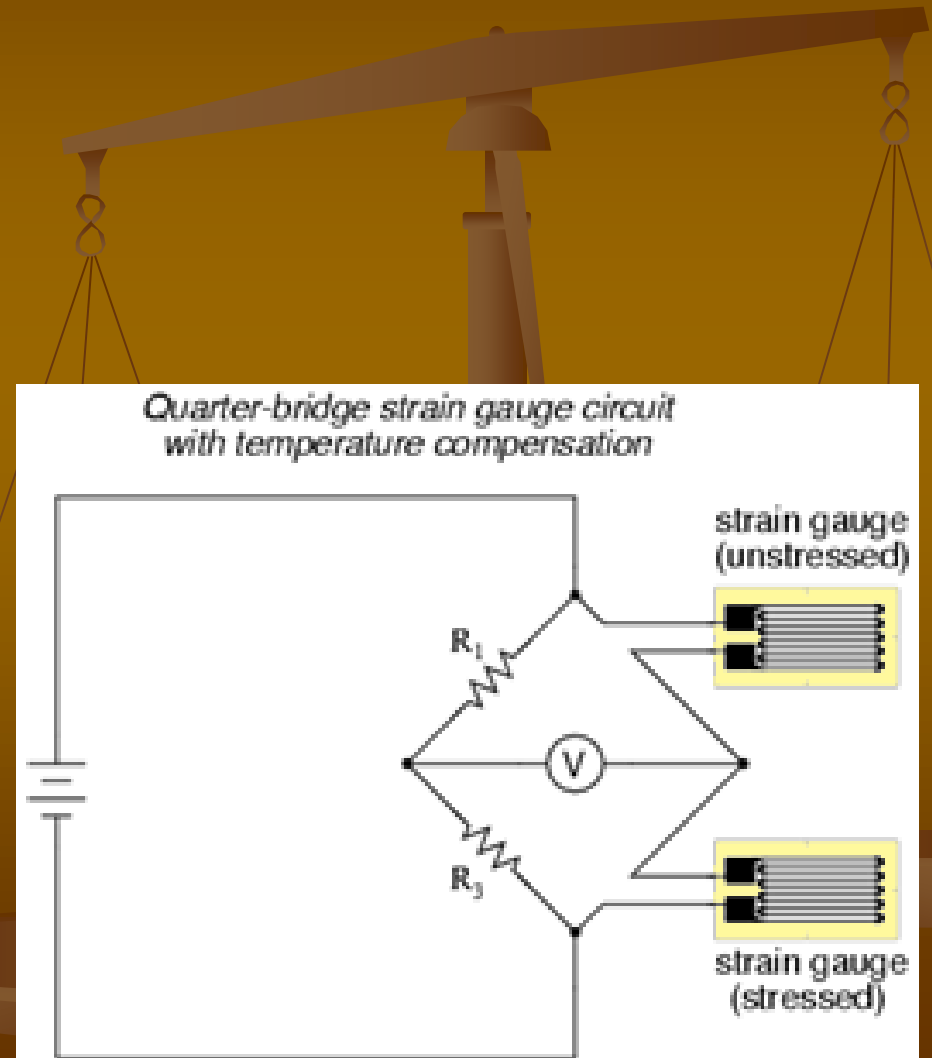
3 wire quarter bridge

- Three wire helps compensate by bypassing the lead resistance for wire 1
- Still leaves wire 2 in series, but its twice as good as the 2 wire.



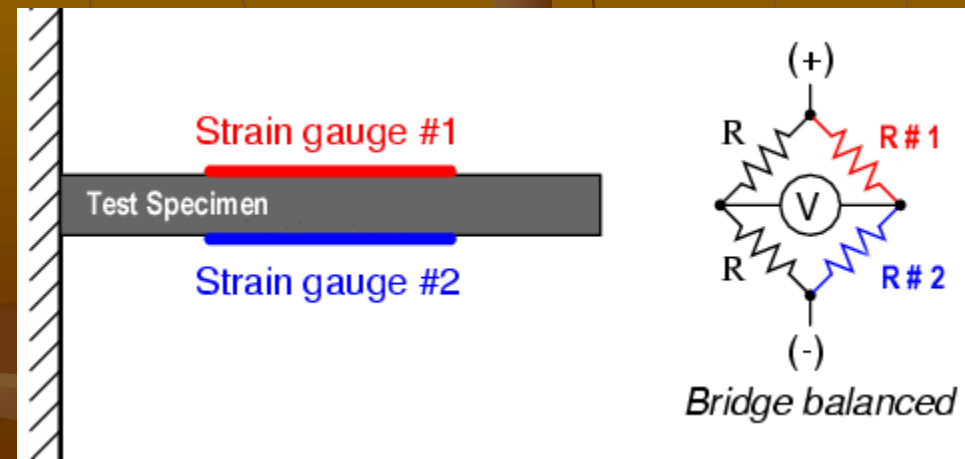
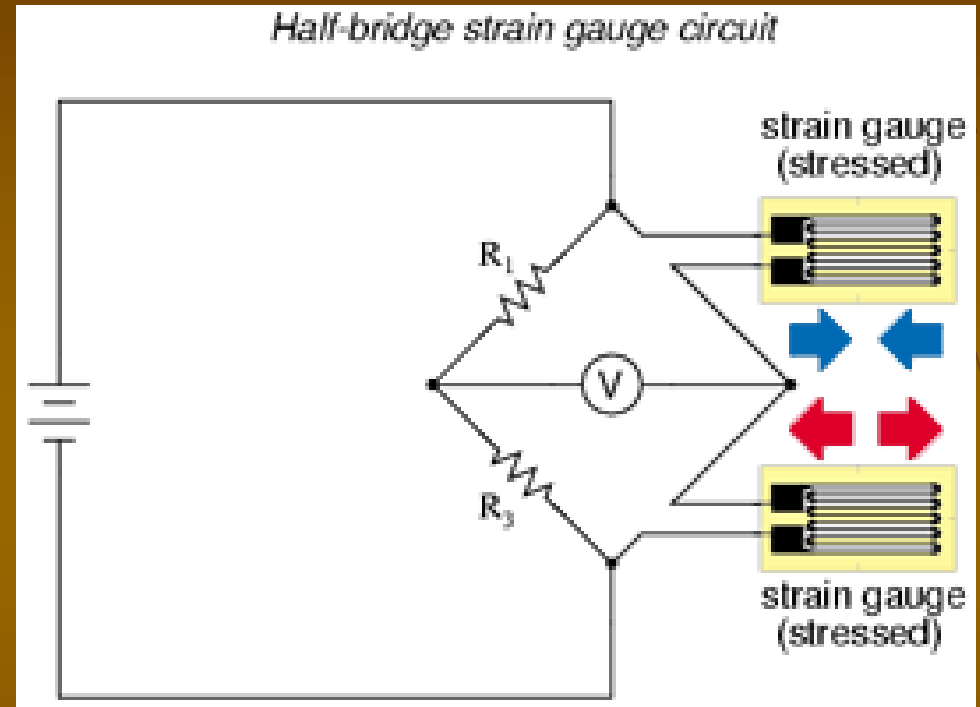
Dummy Half Bridge

- One stressed gauge
- One unstressed gauge
- Totally balances out the lead wire resistance as long as both sets of lead wires are the same length
- Second gauge is isolated from mechanical stress but NOT thermal stress

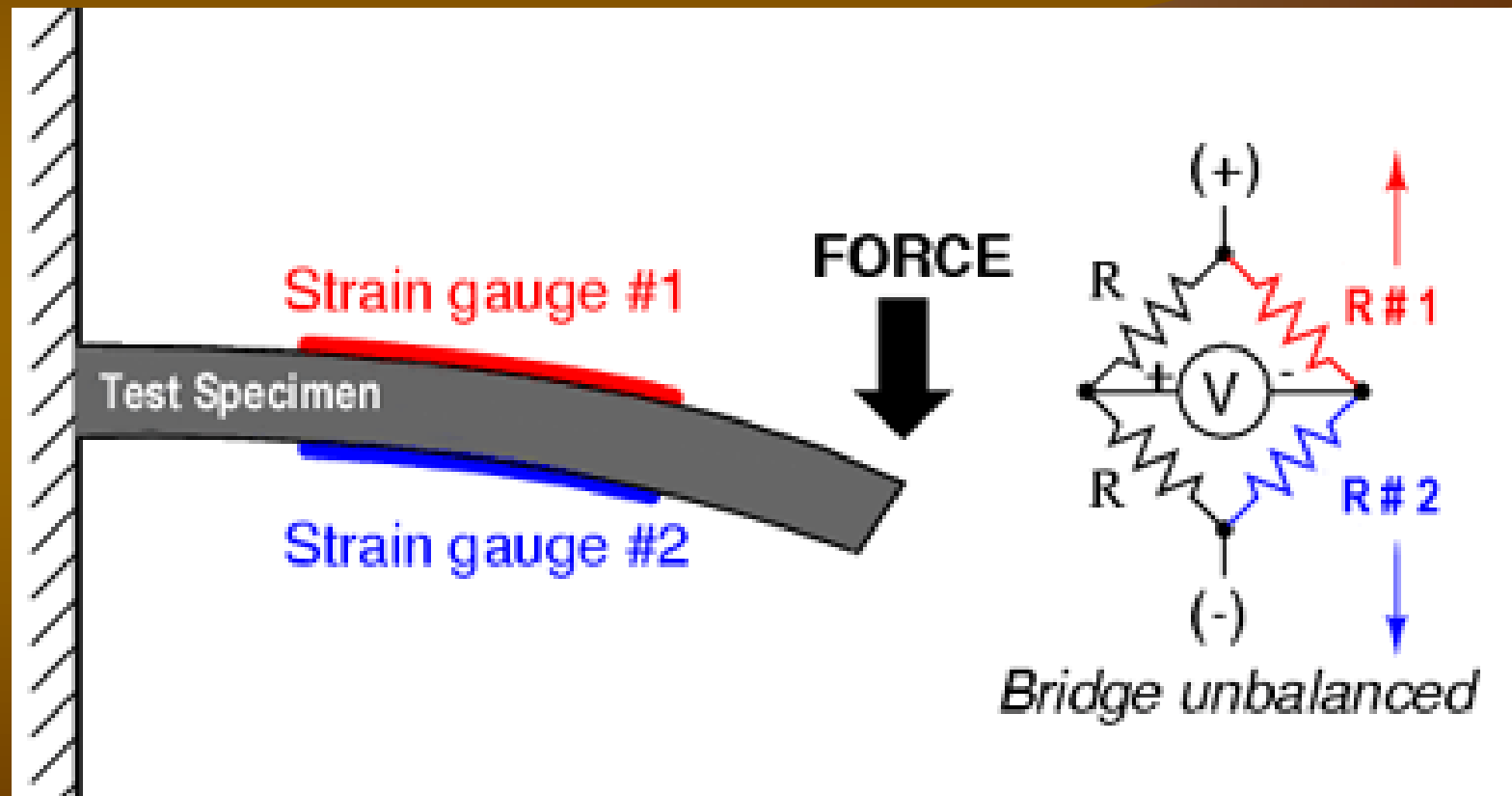


Active half bridge

- Two active gauges
 - One compression
 - One tension
- Divide strain value by 2 because of two active gages

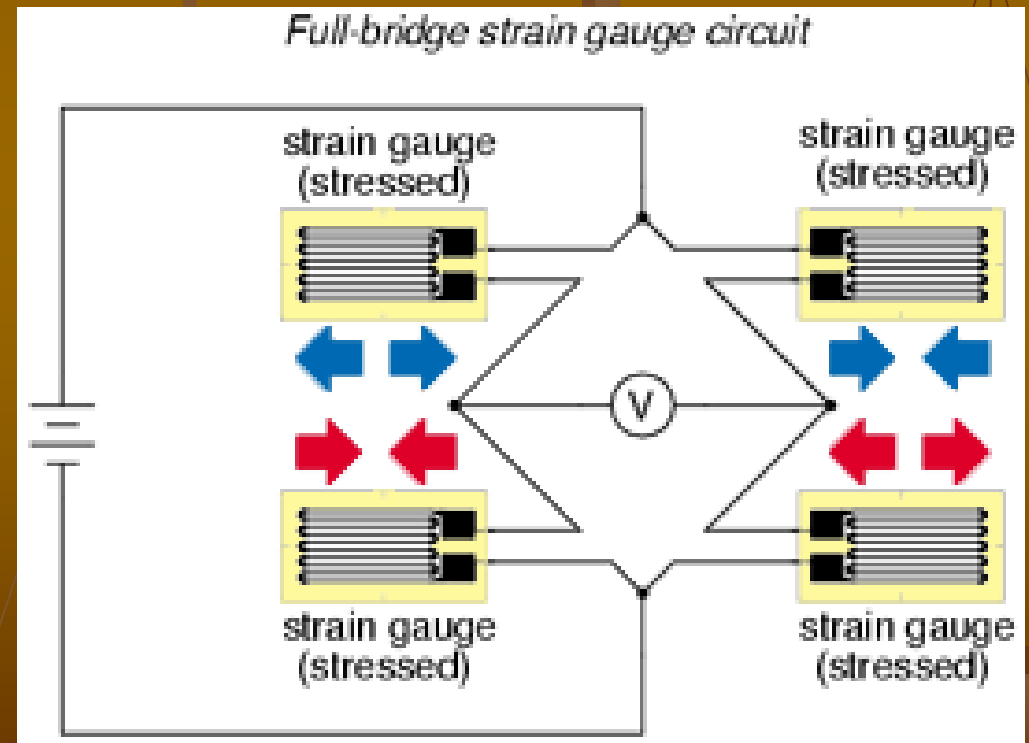


Active half bridge



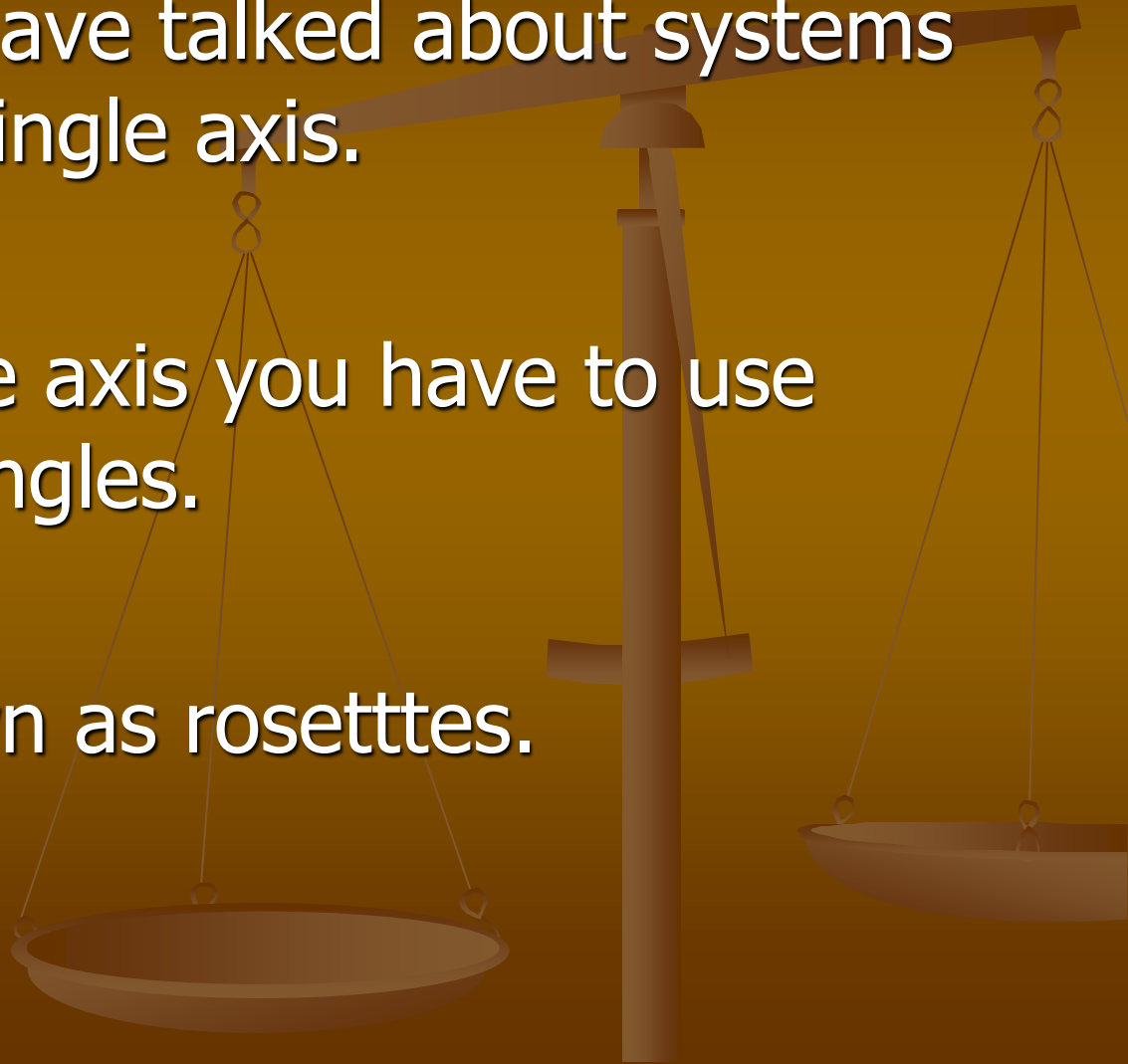
Full Bridge

- Two active gauges in both compression and tension.
- Minimizes all lead errors and temperature effects.
- Increases sensitivity
- 4 x actual strain
- Makes response linear
- Output voltage can be read directly in mv/v/unit instead of having to read resistance of an individual gauge.

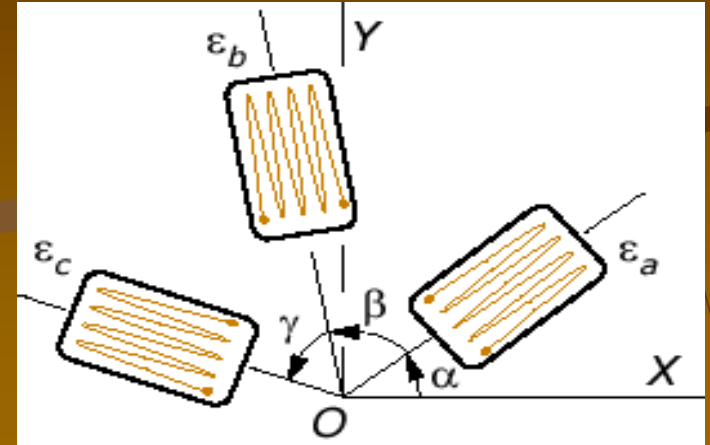


Strain in multiple axis

- Up to now we have talked about systems to read only a single axis.
- To read multiple axis you have to use gauges set at angles.
- These are known as rosettes.



Typical rosette

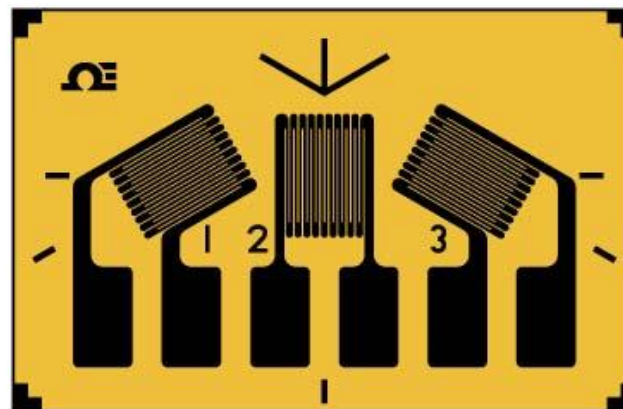
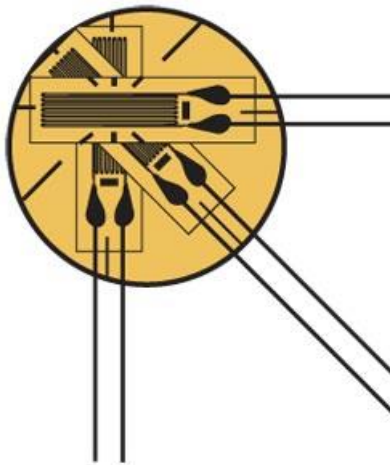
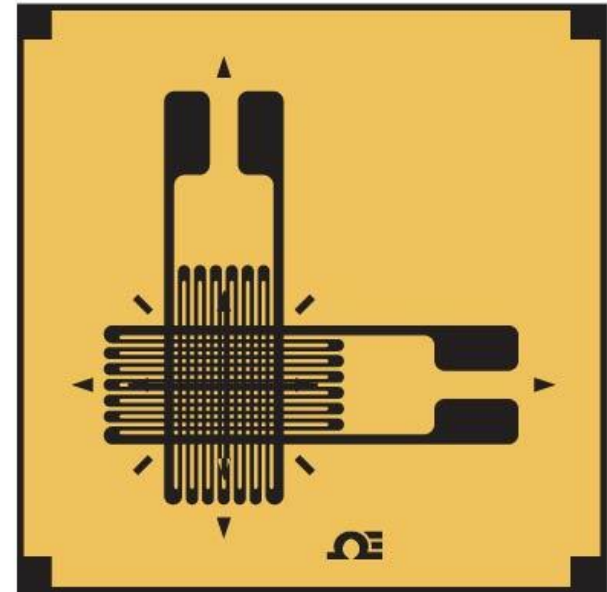
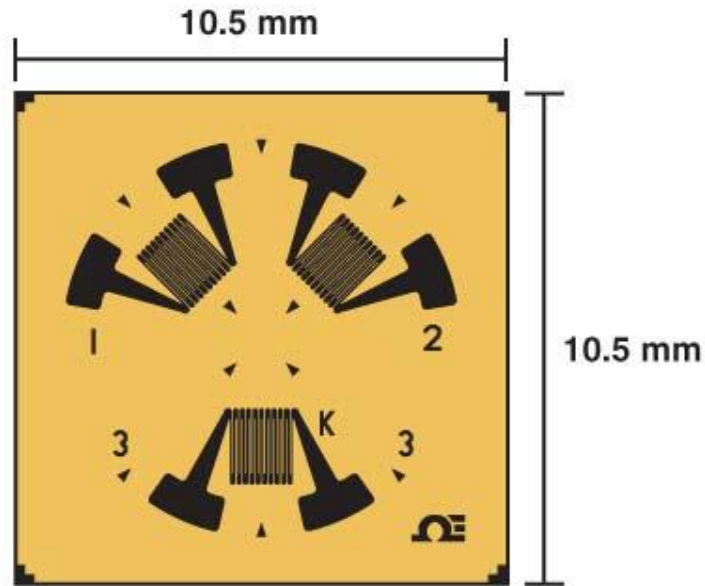


$$\epsilon_a = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2\alpha + \epsilon_{xy} \sin 2\alpha$$

$$\epsilon_b = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2(\alpha + \beta) + \epsilon_{xy} \sin 2(\alpha + \beta)$$

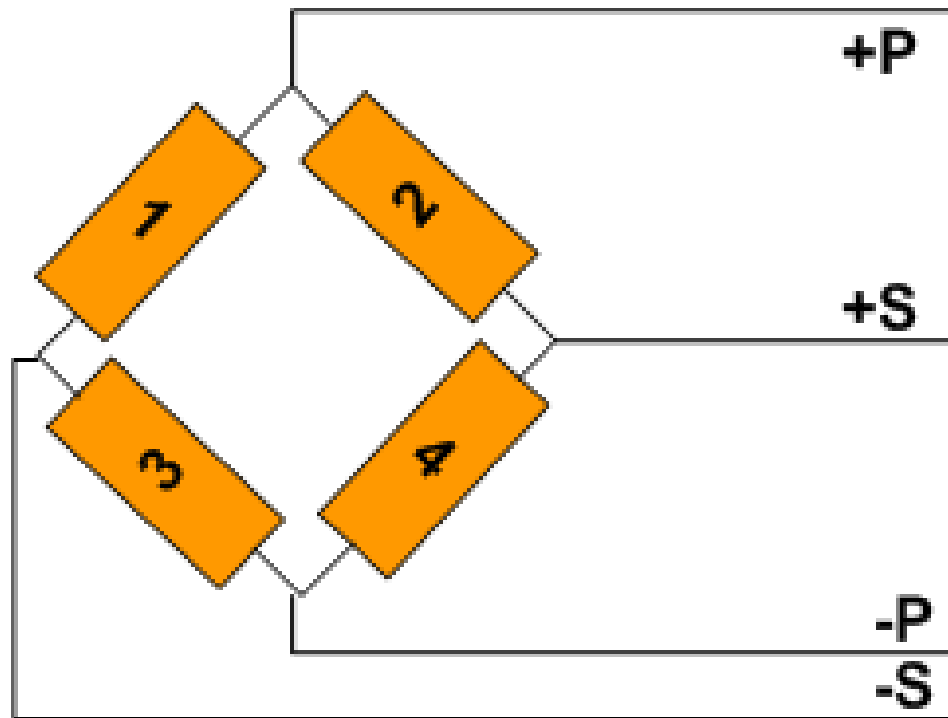
$$\epsilon_c = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2(\alpha + \beta + \gamma) + \epsilon_{xy} \sin 2(\alpha + \beta + \gamma)$$

Typical Rosette Designs

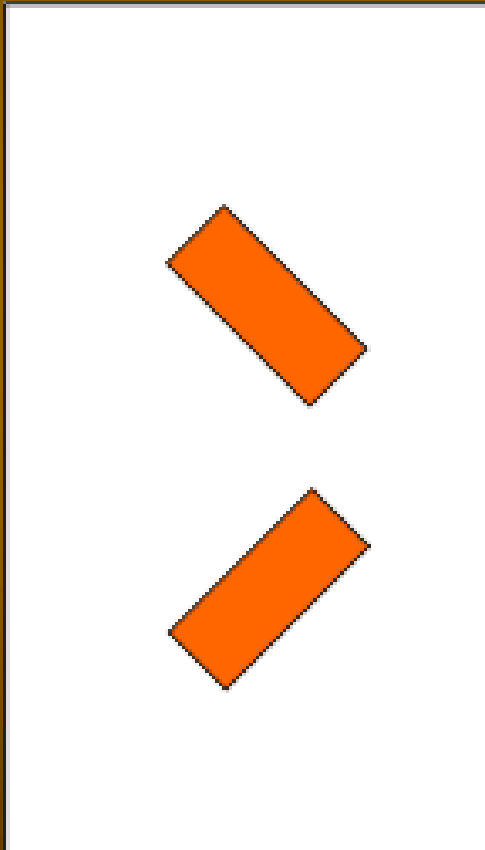


SGD-3/120-RY621

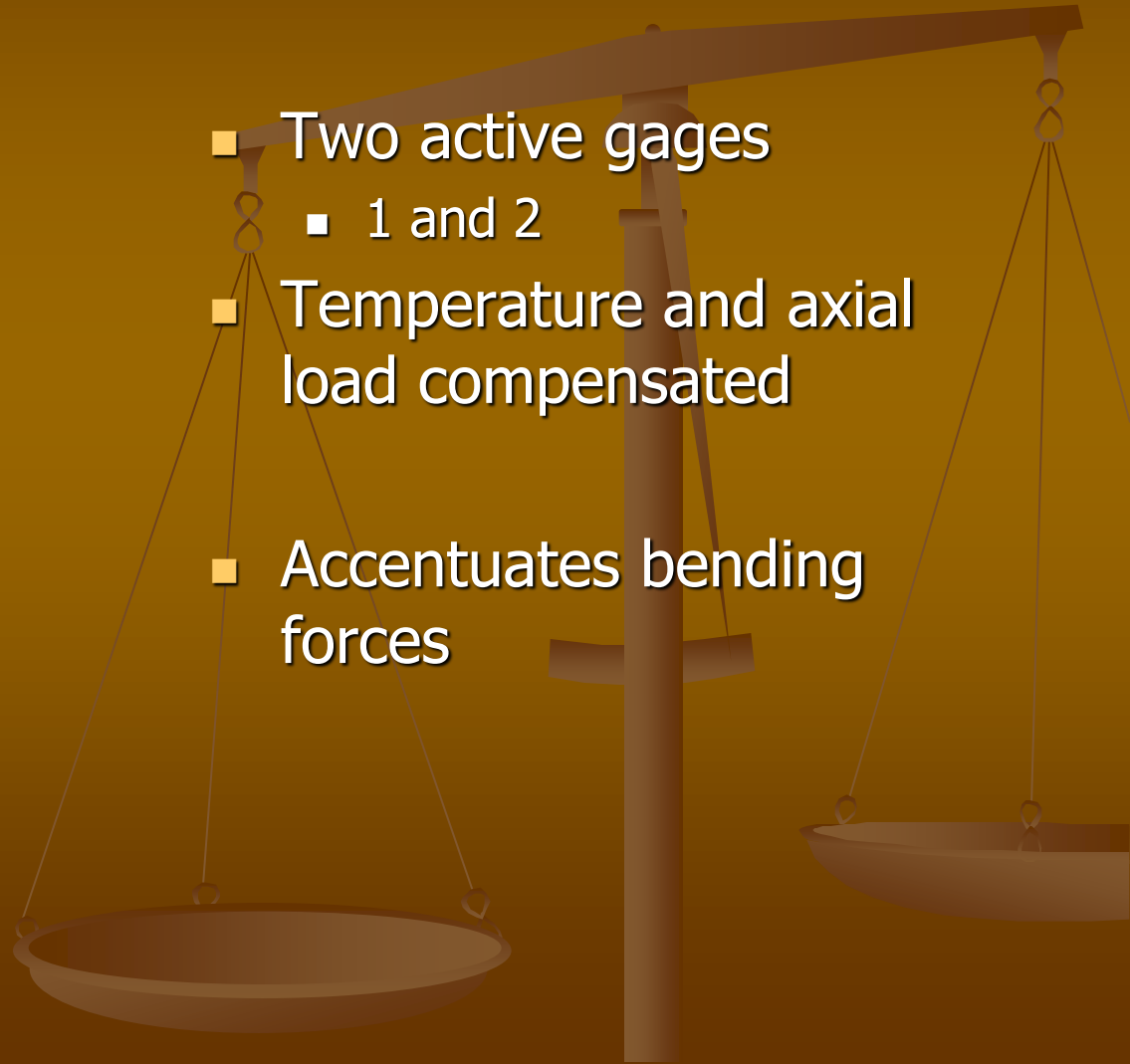
Wiring Layout



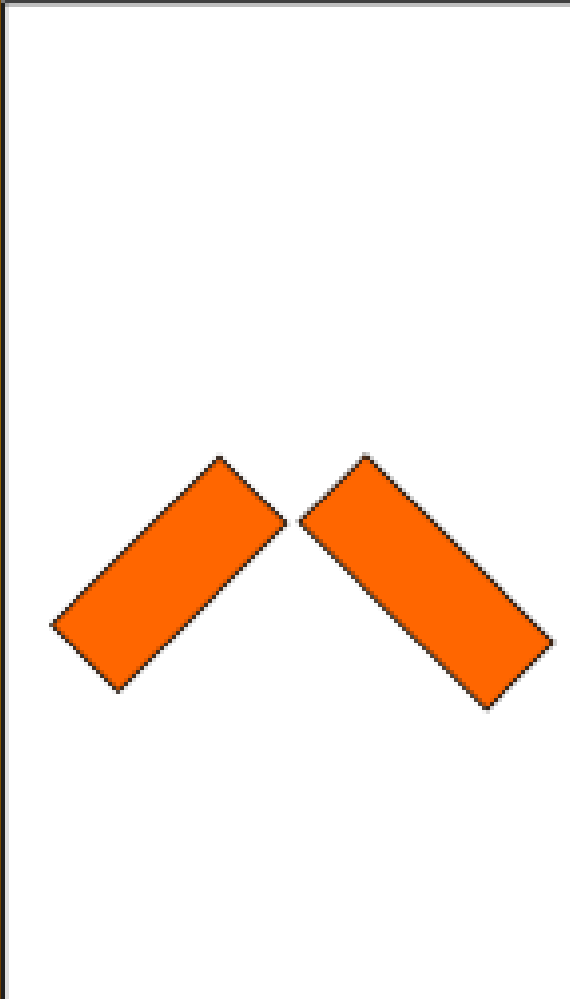
Torsional rod



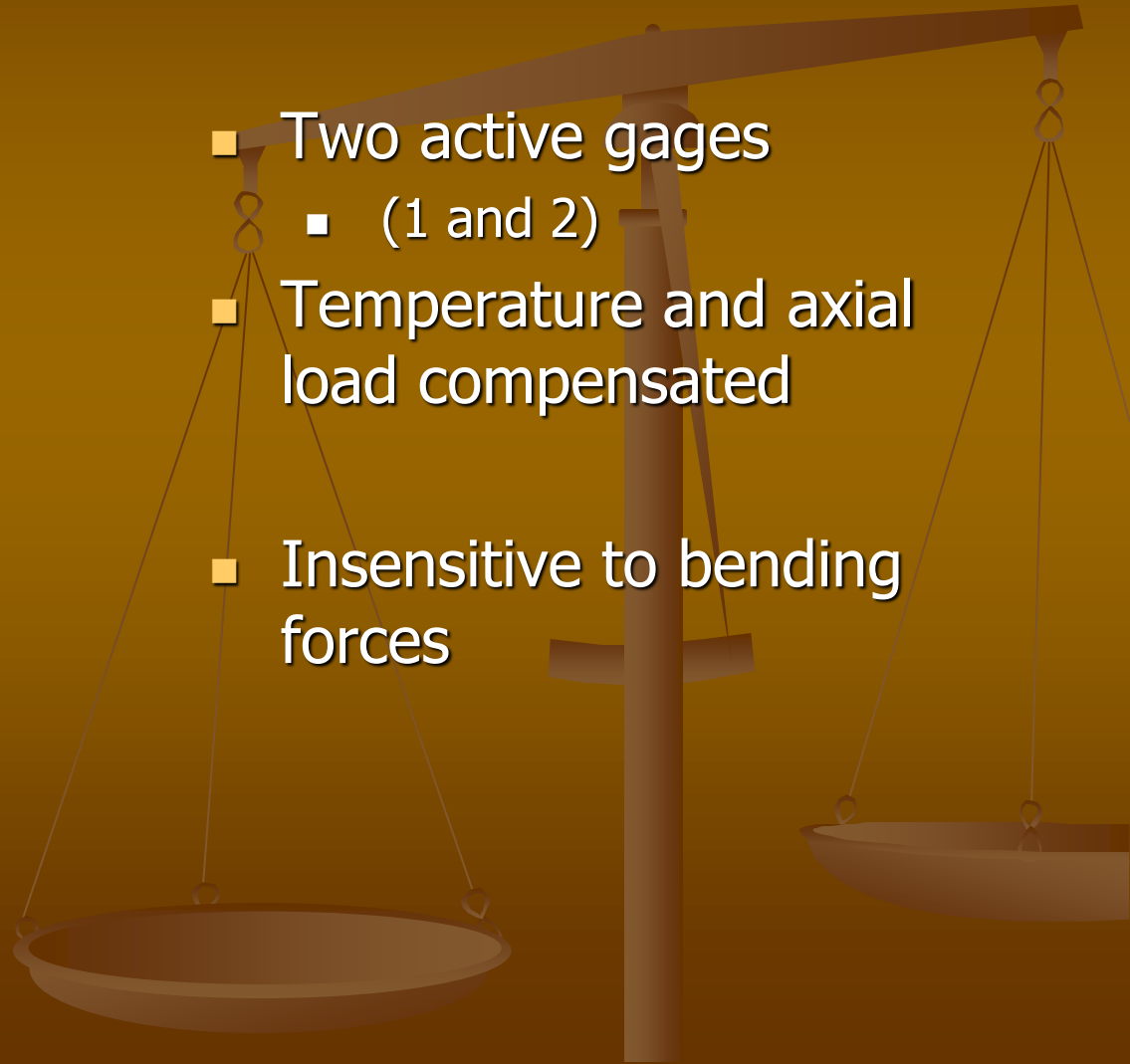
- Two active gages
 - 1 and 2
- Temperature and axial load compensated
- Accentuates bending forces



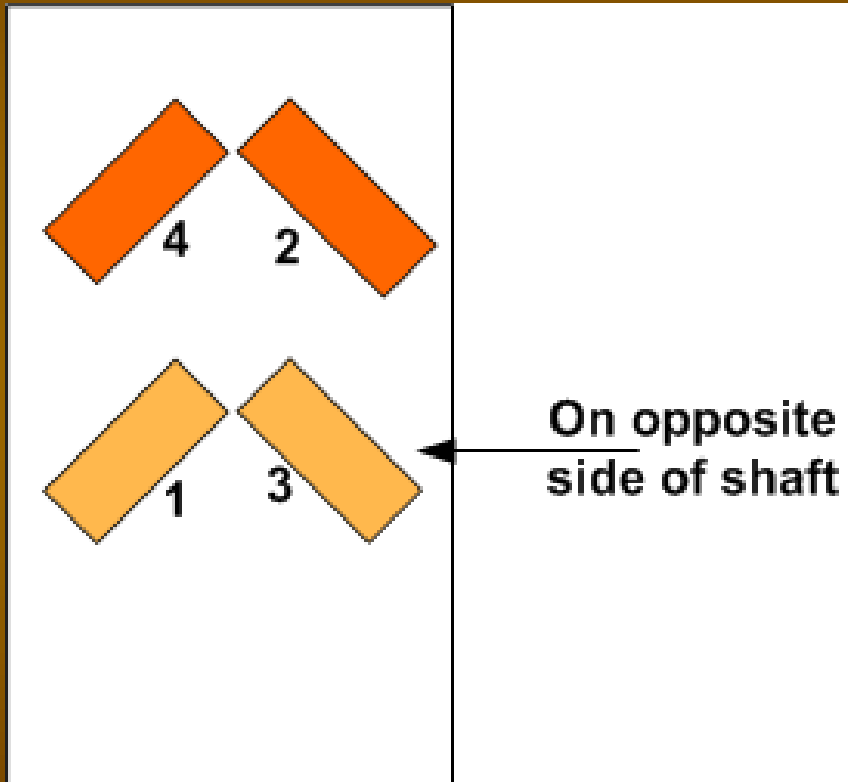
Torsional rod



- Two active gages
 - (1 and 2)
- Temperature and axial load compensated
- Insensitive to bending forces

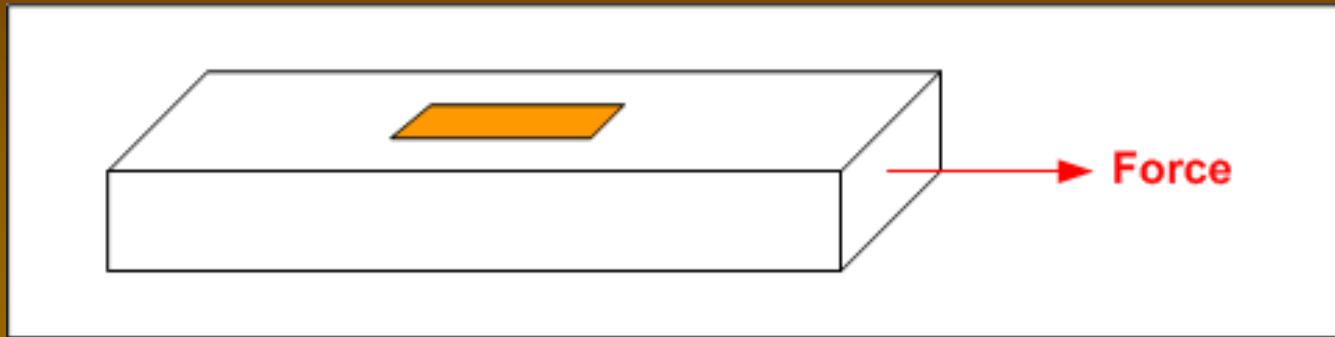


Torsional rod



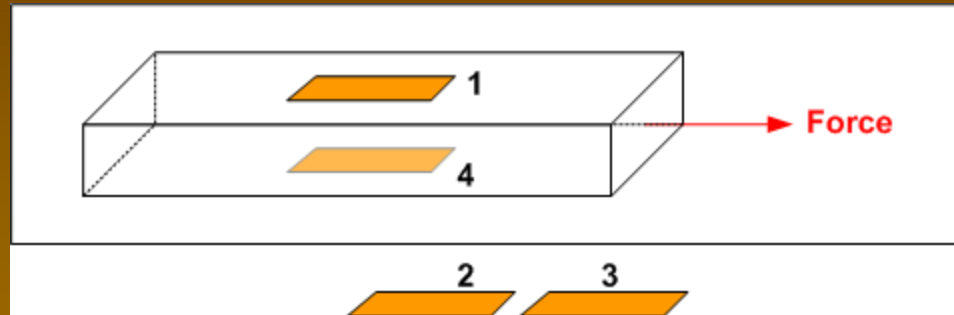
- Four active gages
- Temperature and axial load compensated
- Sensitive to torsion only

Beam



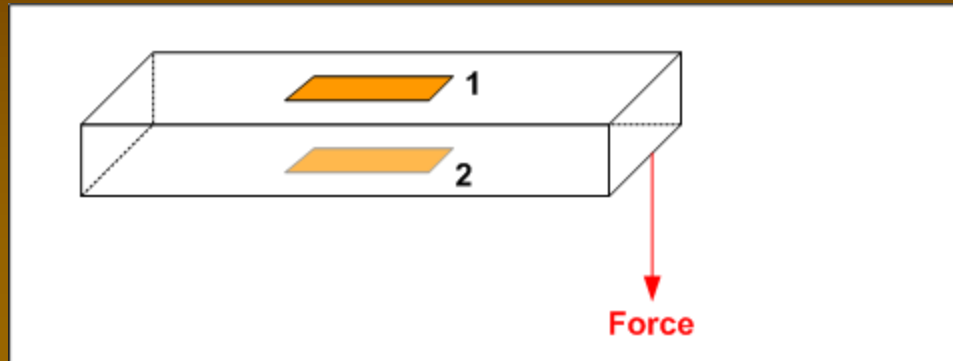
- One active gage
- No compensation for temperature or bending

Beam



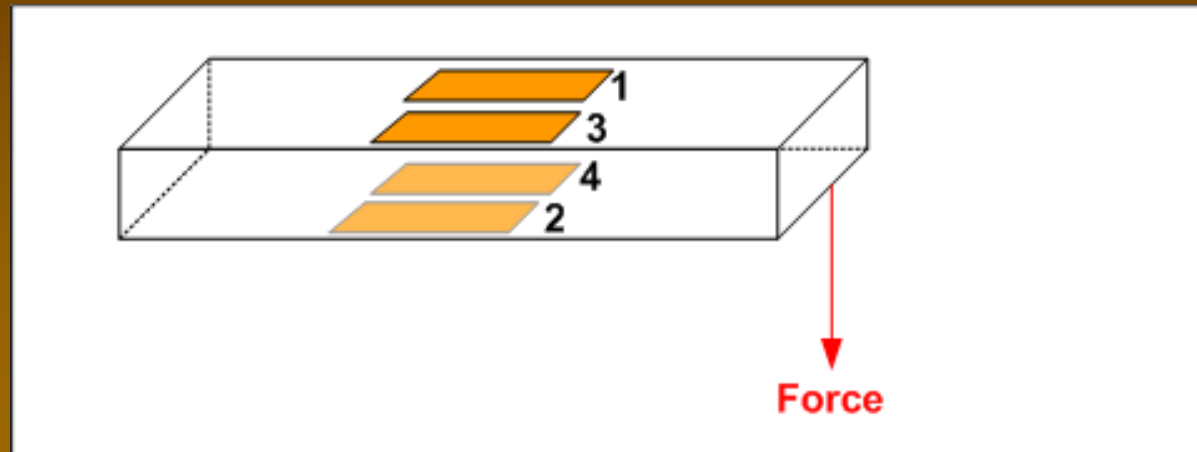
- Two active gages
- No compensation for temperature unless gages 2 and 3 are included as dummy gages

Beam



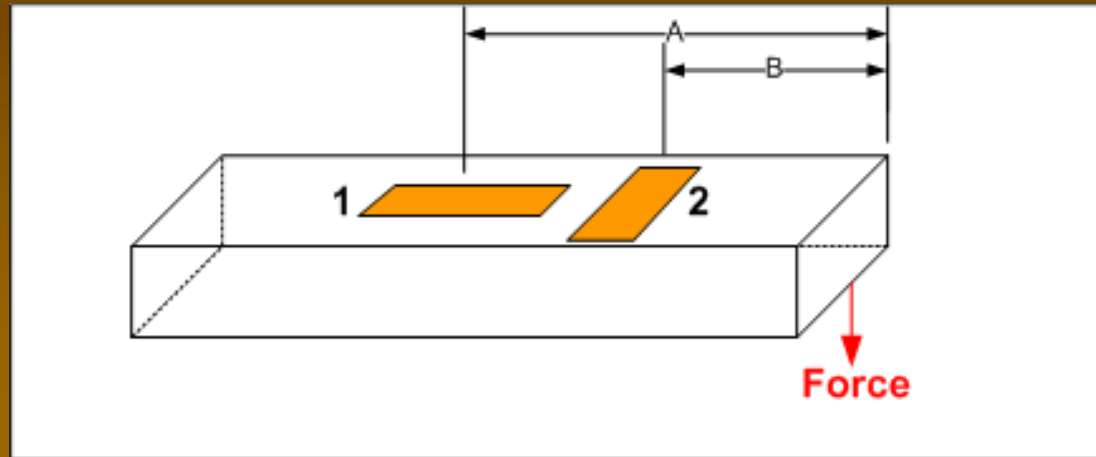
- Two active gages
- Temperature, axial and torsional are compensated

Beam



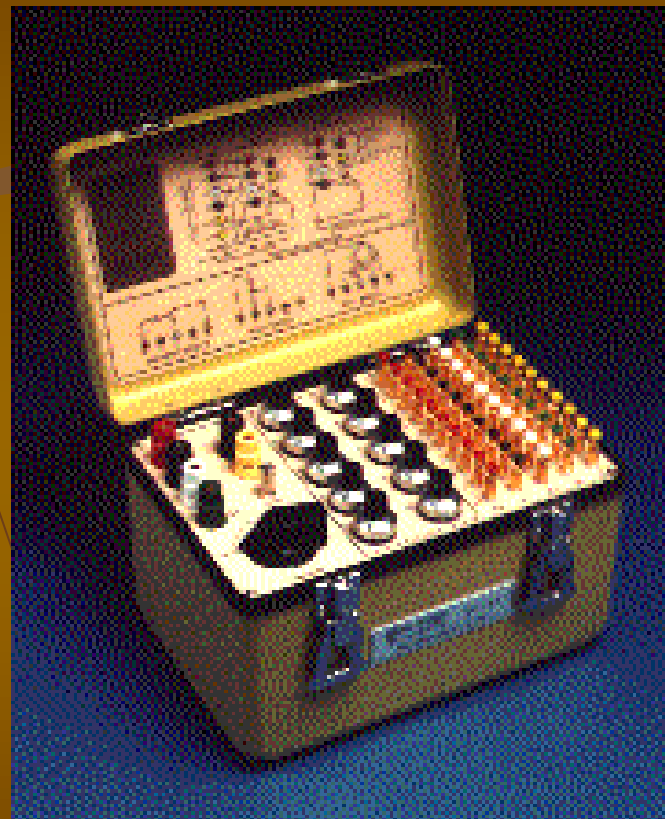
- 4 active gages
- Temperature, axial and torsional are compensated

Beam



- 2 active gages
- Temperature effects are compensated
- axial and torsional are not

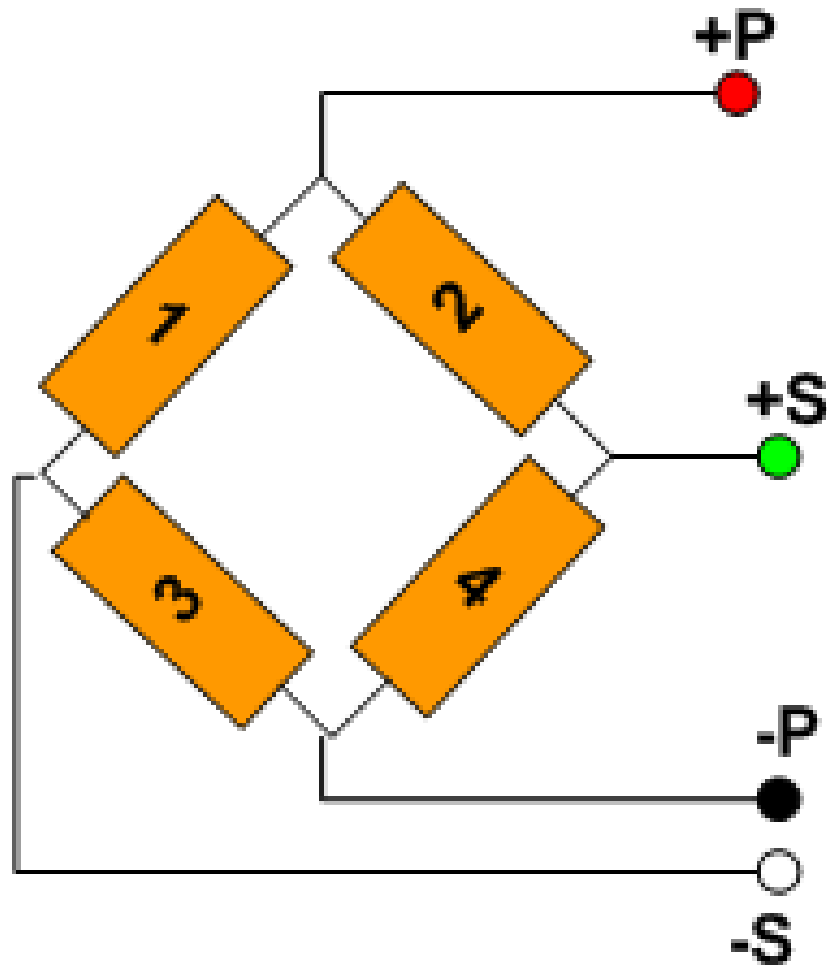
Instrumentation



3800 Wide Range Indicator



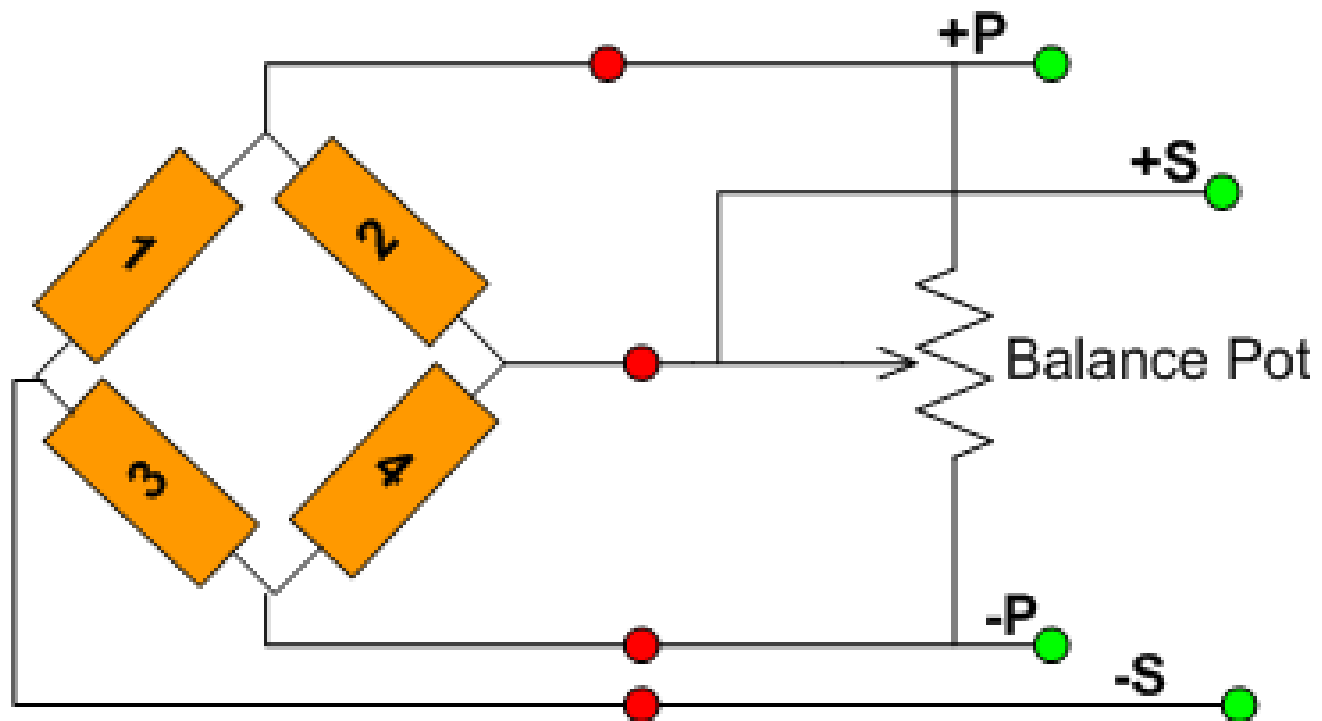
Connections



SB-10 Switch & Balance unit



Balancing a bridge



Strain daq

9219 Universal module



- Low reading rates (100 S/s)
- 24 Bit resolution
- Built in 2.5V excitation
- .125 to 60V ranges
- \$960

Strain daq

9237 4 channel



- High reading rates (50KS/s)
- 24 Bit resolution
- Built in 10,5,3.3 and 2.5V excitation
- 25mv/v input
- \$1064

Strain daq

9236 8 channel



- High reading rates (10KS/s)
- 24 Bit resolution
- Built in 2V excitation
- 29.4mv/v input
- \$1390

Strain daq

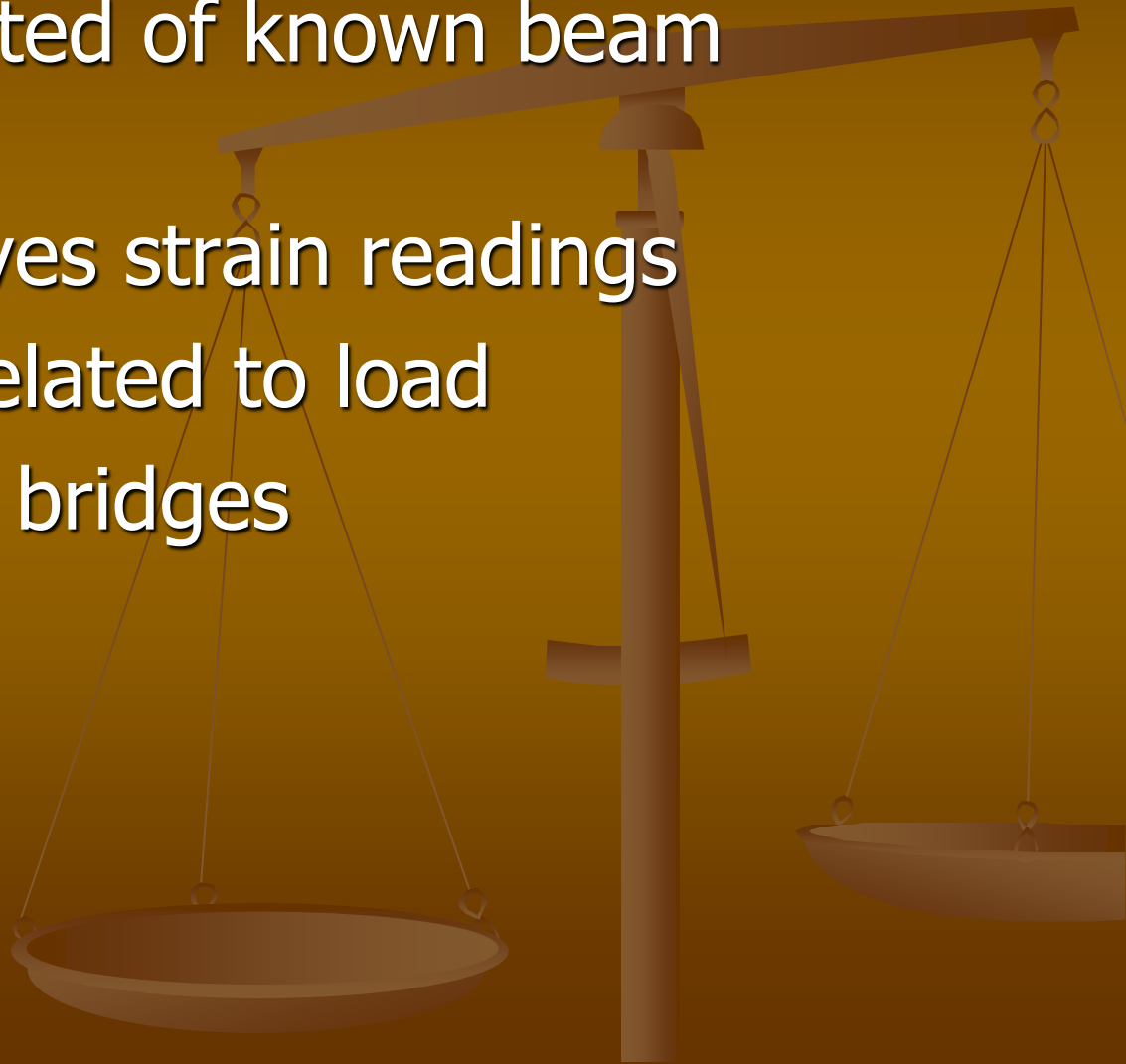
1521 24 channel



- High reading rates (10KS/s)
- 24 Bit resolution
- Built in 0 to 5V excitation
- 42 V/v input
- Built in 10 Hz filter
- \$3789

Load cell

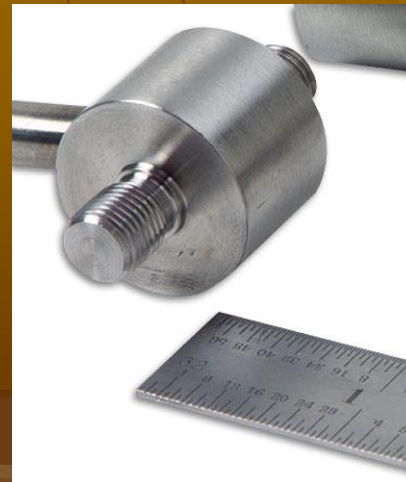
- Device constructed of known beam characteristics
- Strain gauge gives strain readings
- Strain directly related to load
- Most all use full bridges



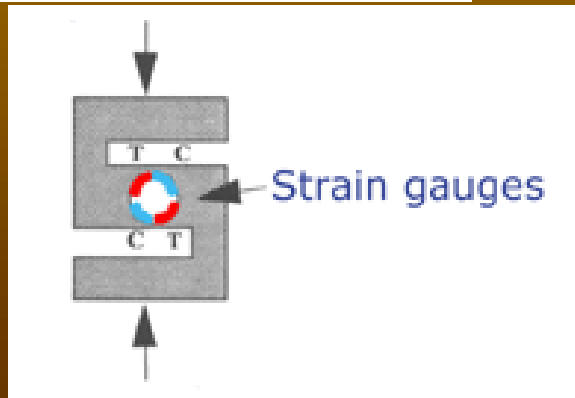
Canister



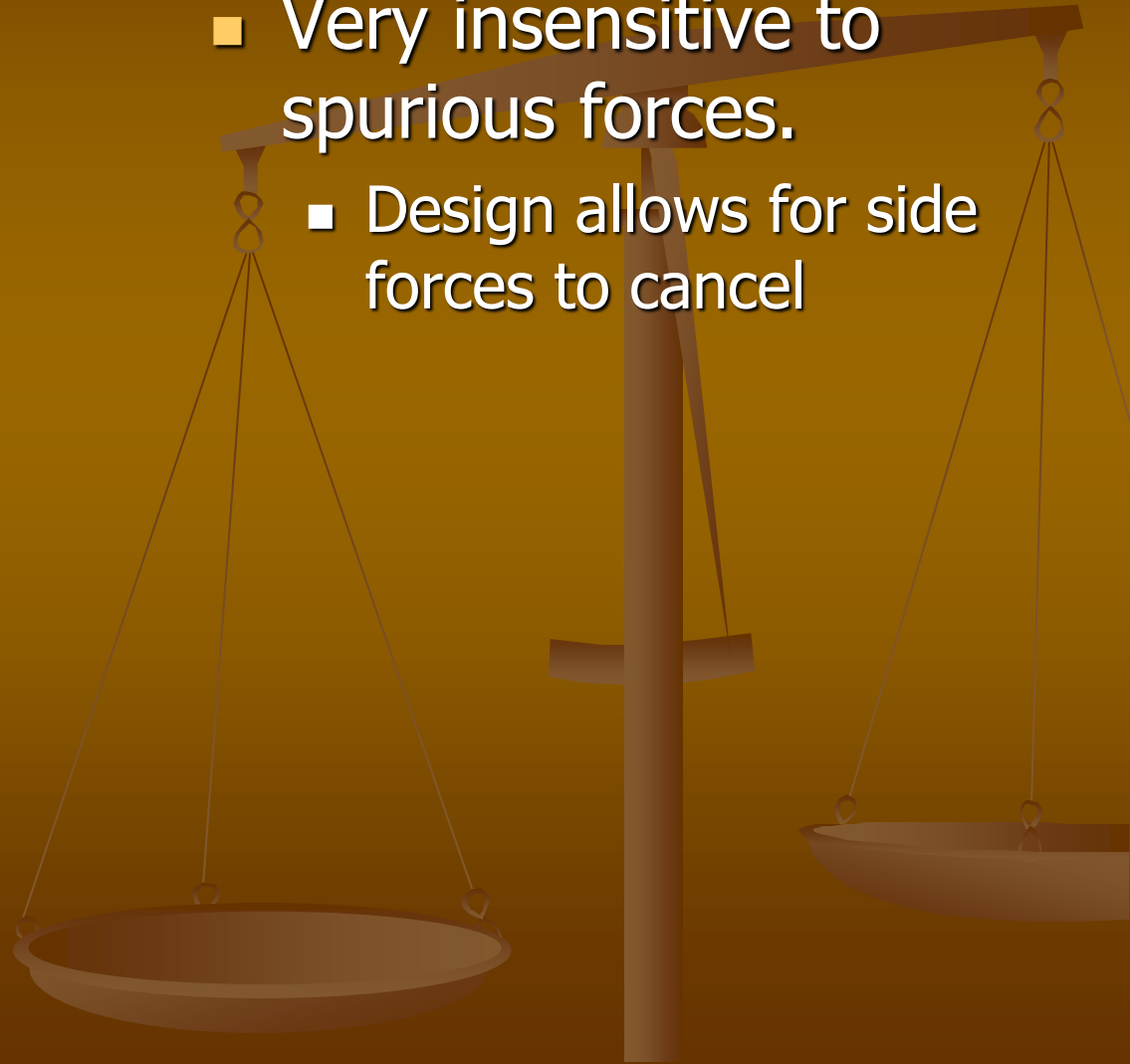
- Some designs are relatively insensitive to loading directions
- Available in low to high ratings



“S” type



- Very insensitive to spurious forces.
 - Design allows for side forces to cancel



Bending Beam



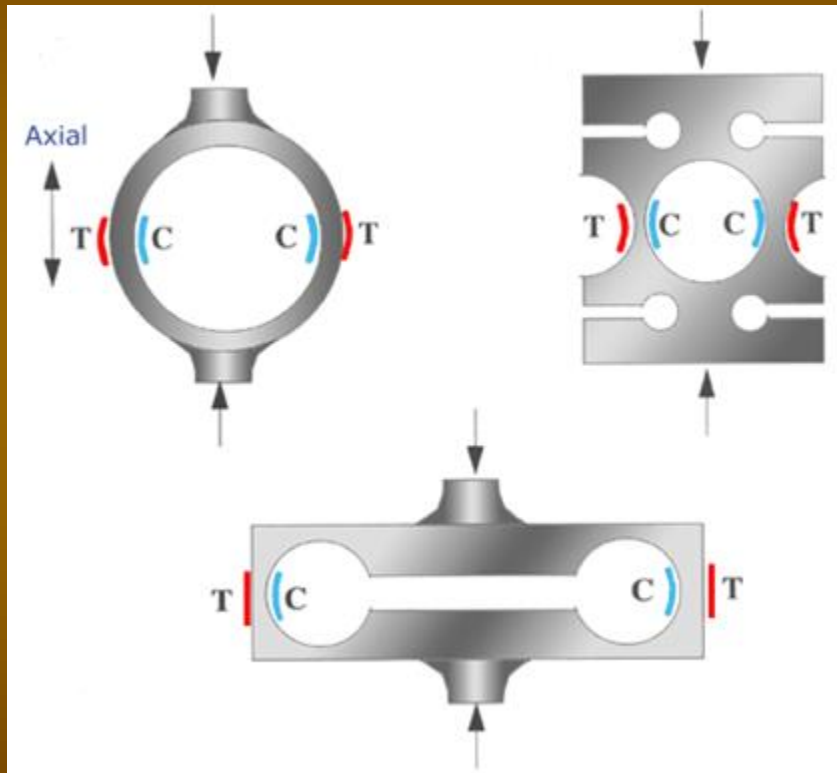
- Good for low load loads
- Proper loading is a must!
- Any flex or torsion loads affect readings

Shear Beam



- Good for medium to high loads
- Low profile for compact installations
- Susceptible to side loads!
- Proper loading a must to get accuracy.

Bending Ring

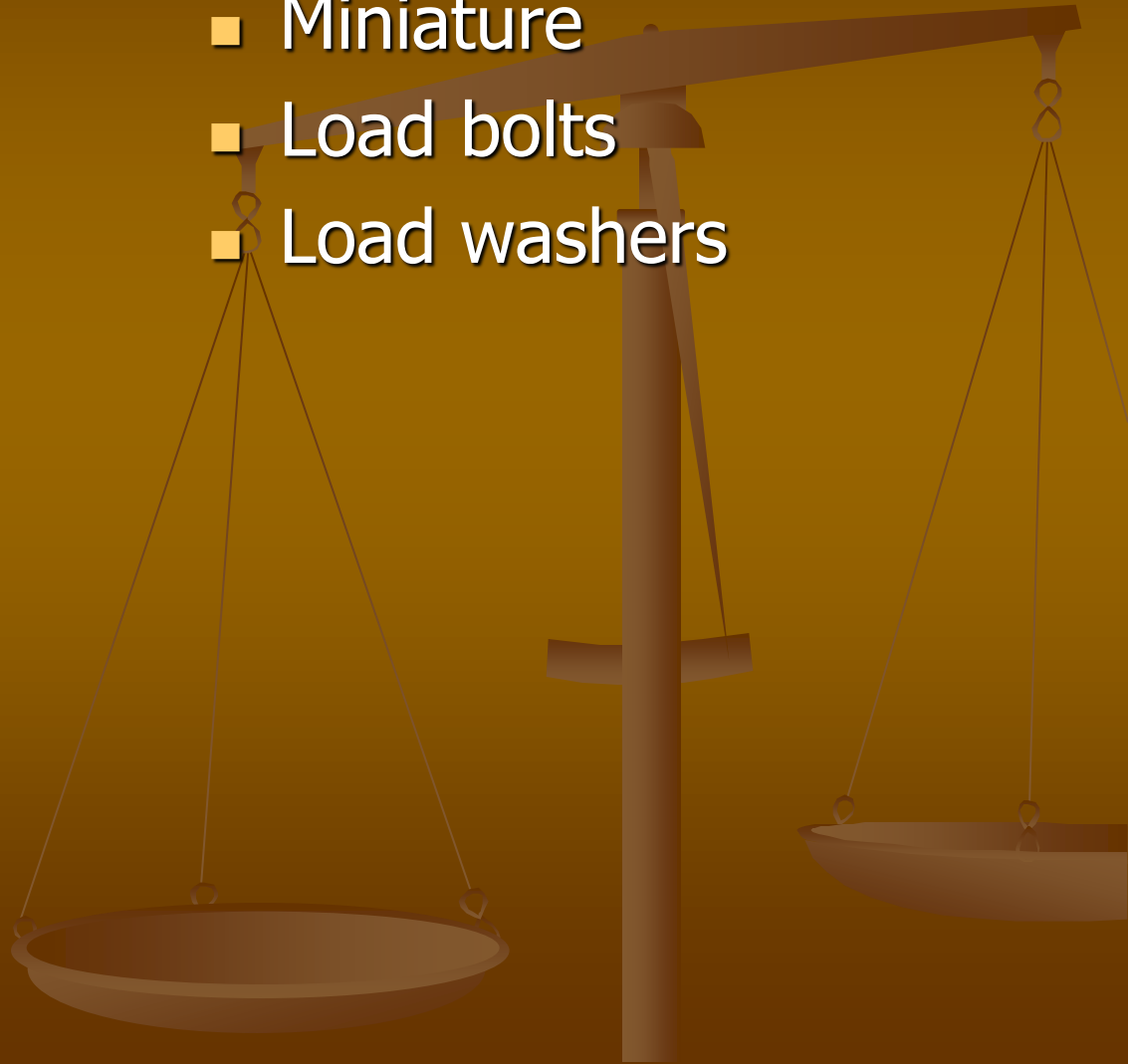


- Moorhouse proving ring
- Still used extensively in standards and materials test equipment

Special load cells



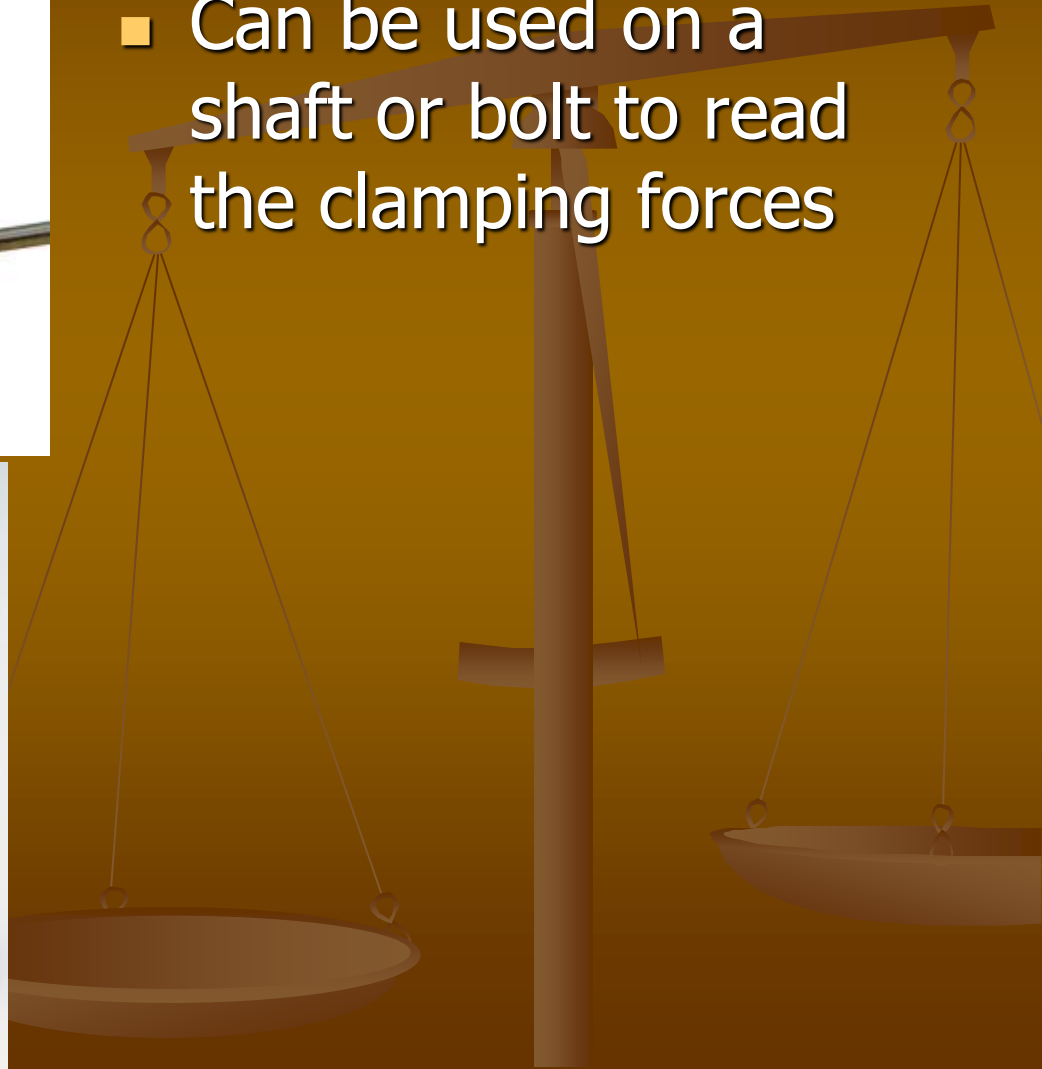
- Miniature
- Load bolts
- Load washers



Load washer



- Can be used on a shaft or bolt to read the clamping forces



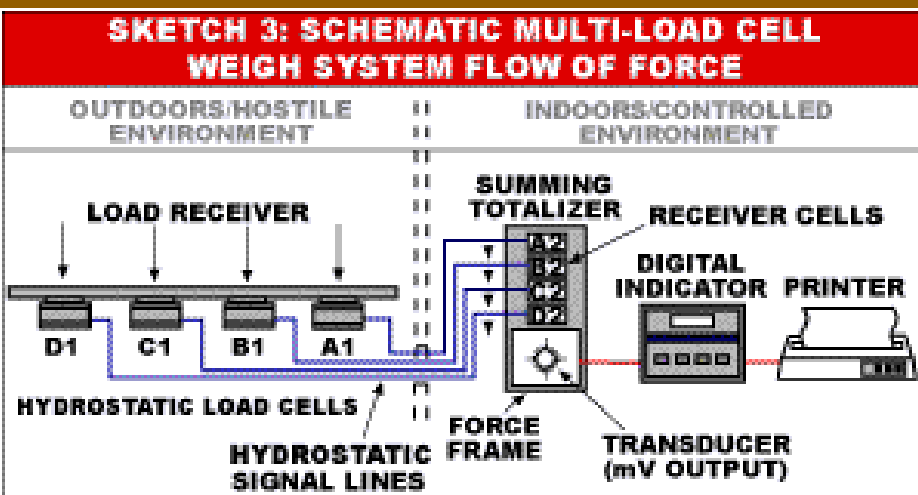
Load bolt



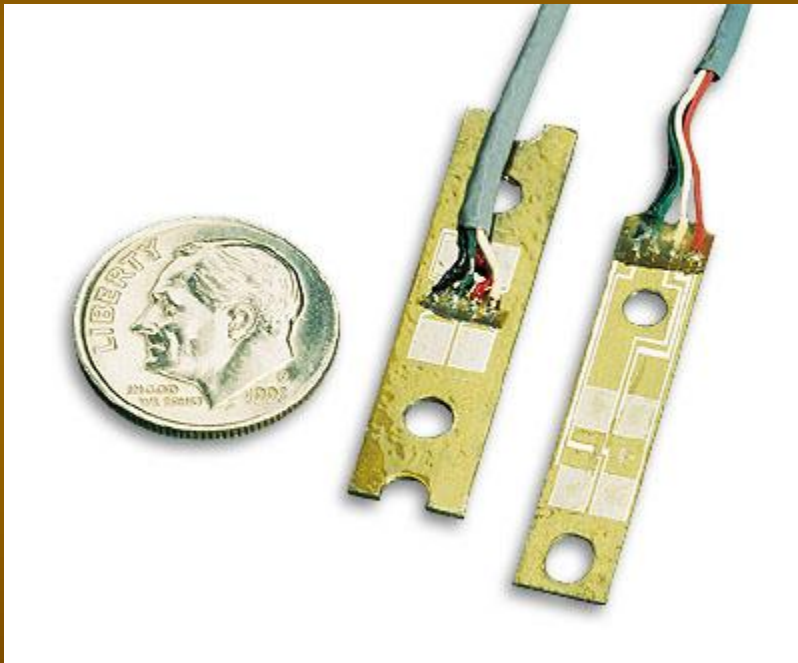
- Hole drilled in end and instrumented
- Designed to read shear forces applied to a bolt

Hydrostaticly compensated

- All electronics are separated from load cell
- Hydraulically connected between cell and receiver.
- Designed for use underwater and harsh conditions such as:
 - Dry docks
 - Outdoor weigh pits
 - Submerged platforms
- Impervious to lightning and electrical noise at the load sensor

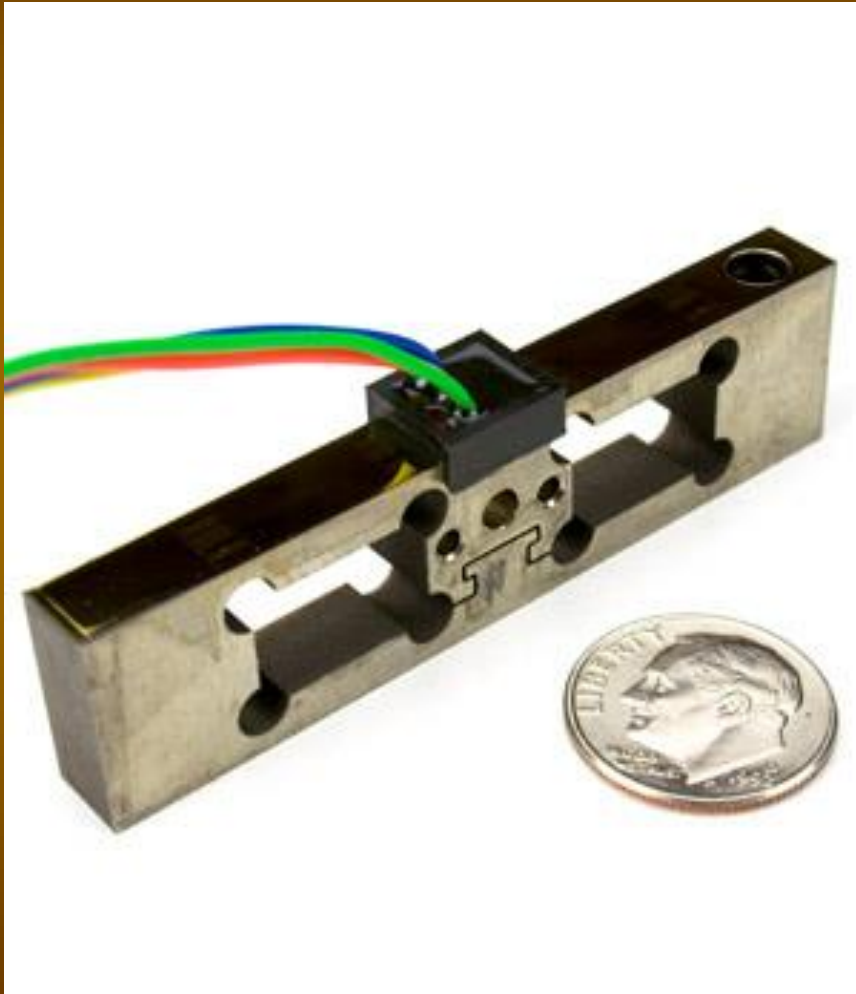


Ultra low force



- Can be purchased to read extremely low forces
- This model down to 113grams full scale
- Some bending beam designs as low as 5 grams FS

Overload prevention



- Various mechanical methods to prevent overloads
 - Canister protection
 - Flex limiters

Load cell types

TYPE OF LOAD CELL	WEIGHT RANGE	ACCURACY (FS)	APPLICATIONS	ADVANTAGES	DISADVANTAGES
Bending Beam	10-5,000 lb	0.03%	Tanks, platform scales,	Low cost, simple construction	Strain gages are exposed, require protection
Shear Beam	10-5,000 lb	0.03%	Tanks, platform scales, off-center loads	High side load rejection, better sealing and protection	
Canister	to 500,000 lb	0.05%	Truck, tank, track, and hopper scales	Handles load movements	No horizontal load protection
Ring and Pancake	5- 500,000 lb		Tanks, bins, scales	All stainless steel	No load movement allowed
Button and washer	0-50,000 lb 0-200 lb typ.	1%	Small scales	Small, inexpensive	Loads must be centered, no load movement permitted

Torque

- Reaction torque
- Rotary torque



Reaction torque sensor

- No moving parts
- Measures the torque generated between the two plates



Rotary torque sensor

- Measures torque on a rotating shaft
- Uses slip rings to make electrical connections



Dynamic load transducer

- Similar to a quartz pressure transducer
- Can be very small



Charge amp

