Force Sensor (7A)

- Force Sensor
- Torque Sensor
- Tactile Sensor

Please send corrections (or suggestions) to youngwlim@hotmail.com.

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Measuring Force

Acceleration

$$a = \frac{F}{m}$$

Pressure

$$P = \frac{F}{A} \qquad (A: \ area)$$

Acceleration

$$\tau = F\,L \qquad (L: \ Lever \ \ arm)$$

Stress and Strain

Normal Stress

- **tensile stress**
- **compressive stress**

Normal (Longitudinal) Strain

- **tensile strain**
- **compressive strain**

Lateral Strain

Shearing Strain
Tangential Strain

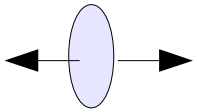
Stress

Normal Stress

A = *cross section area*

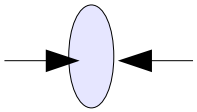
F = *force*

- **tensile stress**



$$\sigma = +\frac{F}{A}$$

- **compressive stress**



$$\sigma = -\frac{F}{A}$$

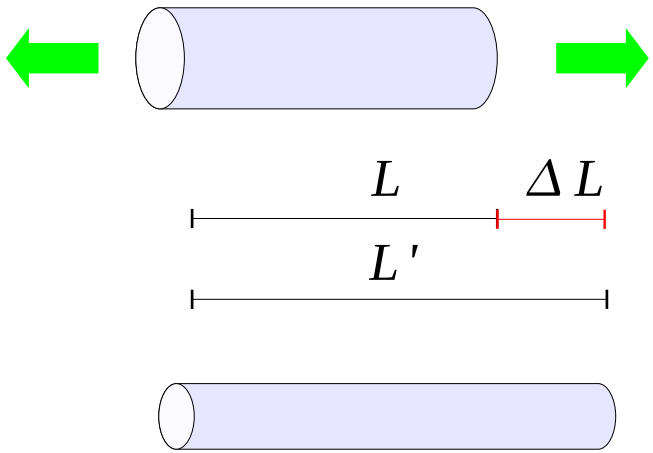
Strain

Normal Stress

A = *cross section area*

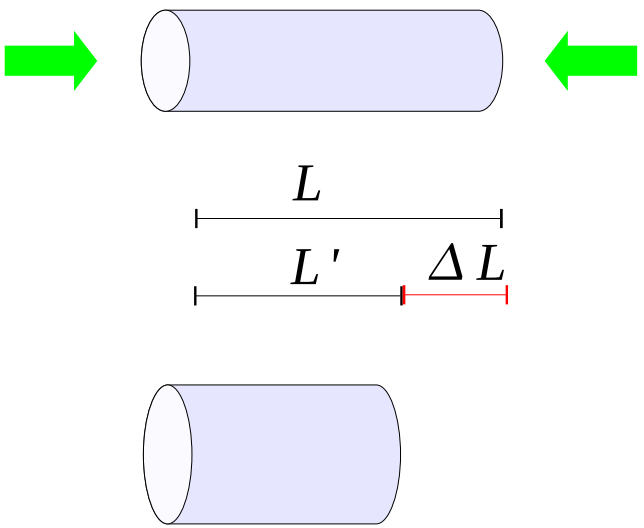
F = *force*

- **tensile strain**



$$\epsilon = +\frac{\Delta L}{L}$$

- **compressive strain**



$$\epsilon = -\frac{\Delta L}{L}$$

Strain Gage

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

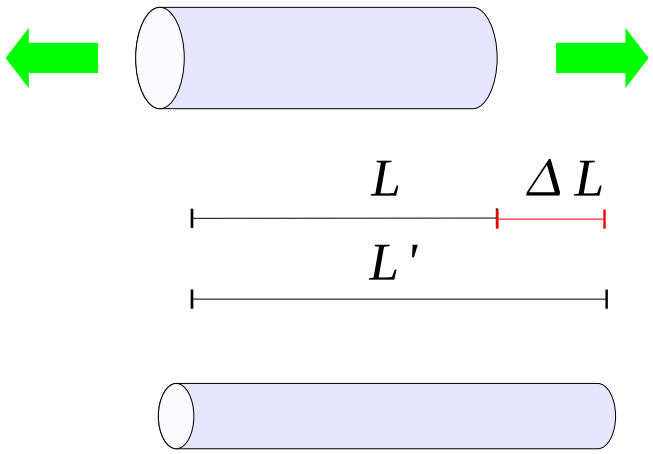
Metal Strain Gauge

- **wire type**
- **foil type**
- **thin film**

Semiconductor Strain Gauge

Piezo-resistive effect

Strain Gage



$$L \rightarrow L + \Delta L$$

$$d \rightarrow d - \Delta d$$

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

$$\frac{\Delta R}{R} = \left[\frac{\Delta R}{R}\right]_{\epsilon} + \left[\frac{\Delta R}{R}\right]_{T}$$

$$\frac{dR}{R} = \left[\frac{dR}{R}\right]_{\epsilon} + \left[\frac{dR}{R}\right]_{T}$$

$$= \frac{1}{R}\left[\frac{\partial R}{\partial L}\frac{\partial L}{\partial \epsilon} + \frac{\partial R}{\partial A}\frac{\partial A}{\partial \epsilon} + \frac{\partial R}{\partial \rho}\frac{\partial \rho}{\partial \epsilon}\right] d\epsilon$$

$$+ \frac{1}{R}\left[\frac{\partial R}{\partial L}\frac{\partial L}{\partial T} + \frac{\partial R}{\partial A}\frac{\partial A}{\partial T} + \frac{\partial R}{\partial \rho}\frac{\partial \rho}{\partial T}\right] dT$$

$$\frac{\Delta R}{R} \approx \frac{dL}{L} - \frac{dA}{A} + \frac{d\rho}{\rho}$$

Load Cell

Beam: spring element

- **Bending beam**
- **Shear beam**
- **Canister beam**
- **Ring-type beam**
- **Helical beam**

Torque Sensor

Moment
Torque

- **rigid body**
- **shear strain**
- **twist angle**

Strain gauge type
Optical type

Tactile Sensor

Touch Sensor
Tactile Sensor
Slip

- **resistive**
- **piezo-electric**
- **optical**

References

[1] http://en.wikipedia.org/
[2] Nam Ki Min, Sensor Electronics, Dong-il Press