Magnetostrictors

$$m_{3311} = 6.6e^{-16}\, m^2 / V^2$$

$$k = 1.6e^{-6} V / m$$

$$r_{33} = 3.25e^{-24} m^2 / V^2 \cdot Pa$$

$$\alpha < 1.0e^{-6}\, ^\circ / C$$

$$k_{rc} = 0.9 MPa\sqrt{m}$$

❖ **Magnetostrictors**

- James Joule, 1840
  Nickel 50 ppm
- 1970's : Giant Magnetostriction
  1,500 ~ 2,000 ppm

Terfenol – D → D_y spropsium

↓ Terbium

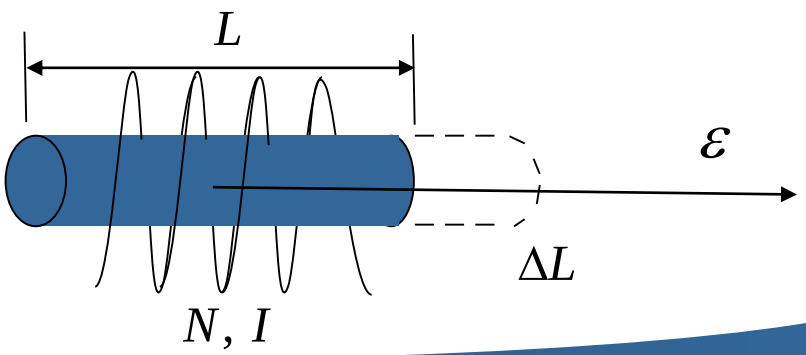
↘ Iron

↘ Naval Ord. Lab.

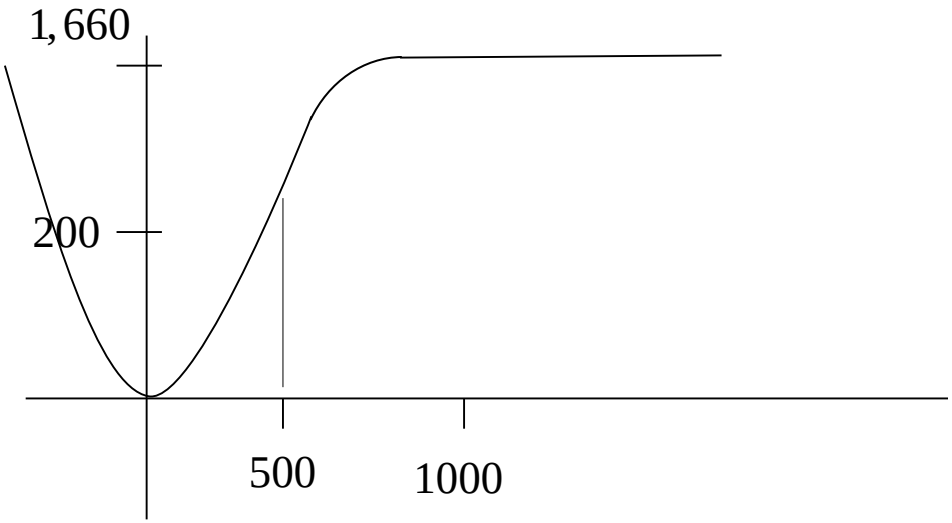
- Phenomena

H : coercive field (A/m or Oersted)

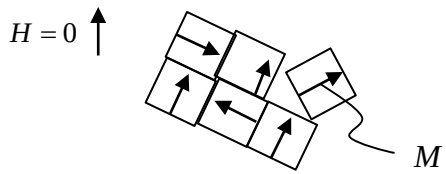
$$H = n\,I$$



Magnetostrictors

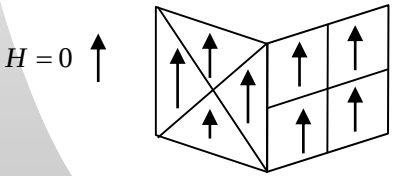


❖ Material Behavior
- Alignment of Magnetic Domains



$\bar{M} = 0$ random alignments

$H = 0$



$M \neq 0$, alignment & strain

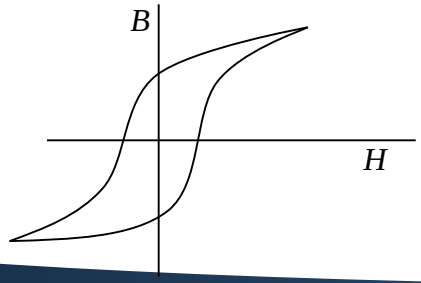
Magnetostrictors

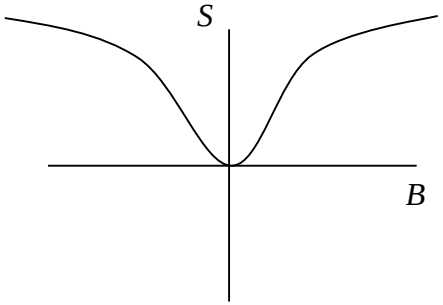
Why is this material important?

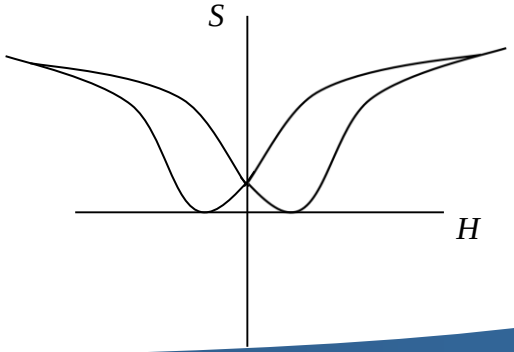
- High force ~piezo's
- Monolithic → Reliable
- Low Voltage of Operation
- Low Hysteresis
- Moderate to Bandwidth (5~10 kHz)
- Moderate Temperature Stability
- No poling – aging Fatigue

- Application
  - Machine tools
  - Isolation → Machinery
  - Sonar → high power, low frequency

- Material Behavior







Magnetostrictors

- Manufacturing Process
  - Dridgmen
  - Free Standing Zone Melt
    Compressive Pre-stress
- Linearization

$$\begin{Bmatrix} S \\ B \end{Bmatrix} = \begin{bmatrix} s^H & n_t^d \\ n^d & \mu^T \end{bmatrix} \begin{Bmatrix} T \\ H \end{Bmatrix}$$

$$y^H = 2.5 \sim 3.5 \times 10^{10}\ Pa : \text{soft}$$

$$\mathrm{y}^B = 5.0 \sim 7.0 \times 10^{10}\ Pa : \text{aluminum}$$

$$\mathrm{y}^H = y^B(1-k^2) \rightarrow k = 0.7$$

$$0.75$$

$$\alpha = 1.5 \rightarrow 2 \times 10^{-8}\ m/A$$

$$\mu^T = 9.2 \times \underbrace{4\pi \times 10^{-7}}_{\mu_o}\ Tesla\ m/A$$

$$\mu^S = 4.5 \times 4\pi \times 10^{-7}$$

$$\mu^S = \mu^T(1-k^2)$$

Magnetostrictors

Force - Voltage Sensors

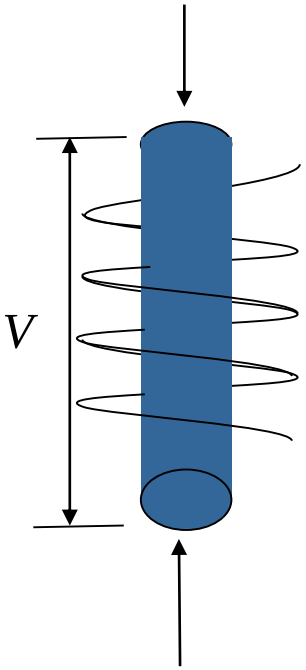
$$\Downarrow$$

$$B = d\,T$$

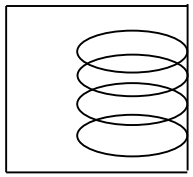
$$\varphi = B\,A\,, \qquad V = -N\frac{d\varphi}{dt}$$

$$V = -NA\,d\,\frac{dT}{dt}$$

$$= -N\,d\,\frac{dT}{dt}$$



$B = 0$



current introduced!

Magnetostrictors

- Energy Density

$$E = k^2 (\frac{1}{2} B_{\max} H_{\max})$$

$$= \frac{\mu^T}{2} (k H_m)^2$$

$$E_m = 19.2 \times 10^3 \ J / m^3$$

$$PZT - 4 \qquad 2 \ kJ / m^3$$

$$PZT - 5H \qquad 620 \ kJ / m^3$$