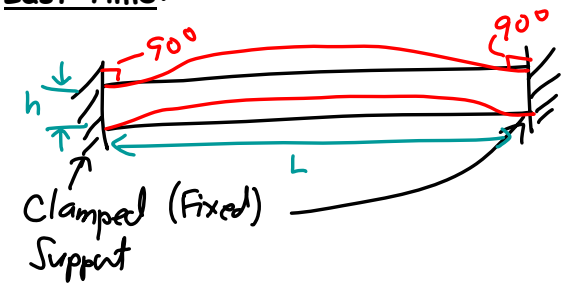
- Announcements:
- Discussion Time Change?
  - 5-6: still pending
- Lecture room change: inquired
- ---
- Today:
- Reading: Senturia, Chapter 1
- Lecture Topics:
  - Benefits of Miniaturization
  - Examples
    - GHz micromechanical resonators
    - Chip-scale atomic clock
    - Micro gas chromatograph
- ---
- Last Time:



⇒ Eq. for Resonance Freq.:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = 1.03\sqrt{\frac{E}{\rho}}\frac{h}{L^2} \qquad (1)$$

where $E \triangleq$ Young's modulus [GPa]

$\rho \triangleq$ density [kg/m^3]

$h \triangleq$ thickness [m] $L \triangleq$ length [m]

Example: $L = 40\mu m$, $h = 2\mu m$

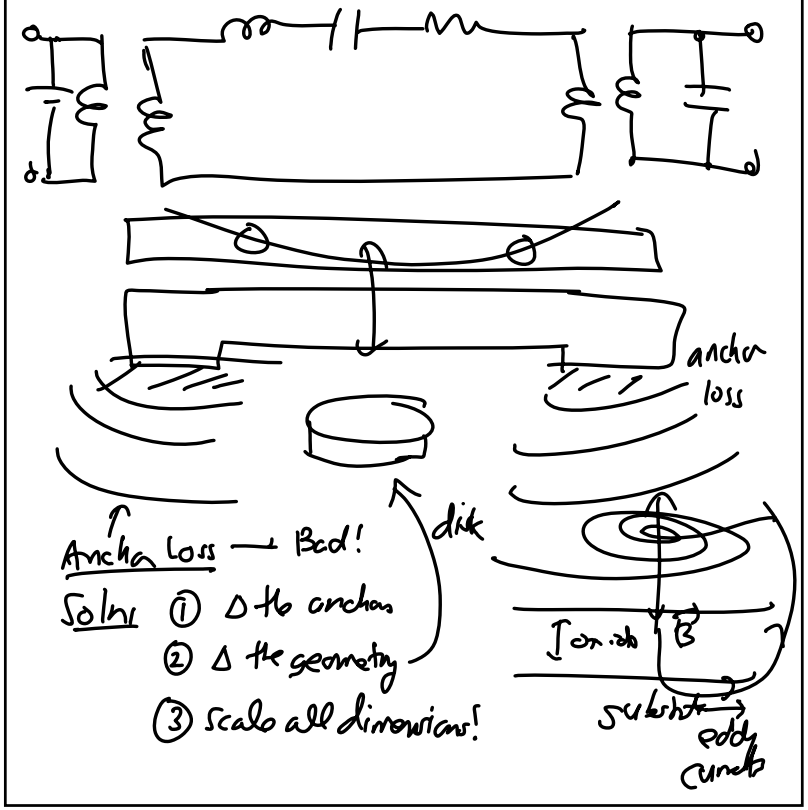
polysi → $E = 150$ GPa, $\rho = 2300$ kg/m^3

$\therefore f_0 = (1.03)\sqrt{\frac{150G}{2300}}\frac{2\mu}{(40\mu)^2}$ → $f_0 = 10.4$ MHz

acoustic velocity = 8,076 m/s

Get high freq.
⇒ scale L → $L = 4\mu m$ → $f_0 = 1.04$ GHz!

But see remarks!



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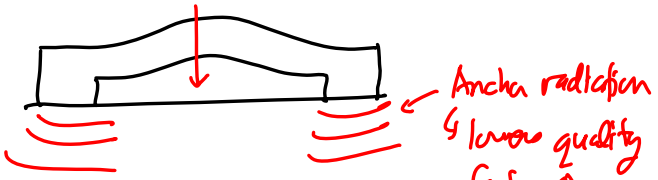
Remarks.

① Eq. (1) not accurate when $L \approx h$. (must take into account rotary inertias)

② When $L \approx h$ (or when it isn't more than $10 \times h$), anchor losses become an issue



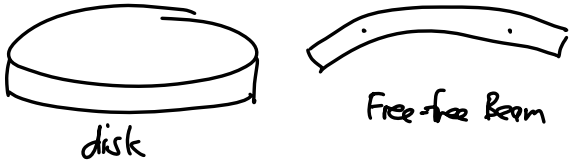
③ Solution: scale all dimensions

(i) Scale only L by S: $f_0 \sim \frac{1}{S^2}$

(ii) Scale all dimensions (L and h): $f_0 \sim \frac{h}{L^2} \sim \frac{S}{S^2} \sim \frac{1}{S}$

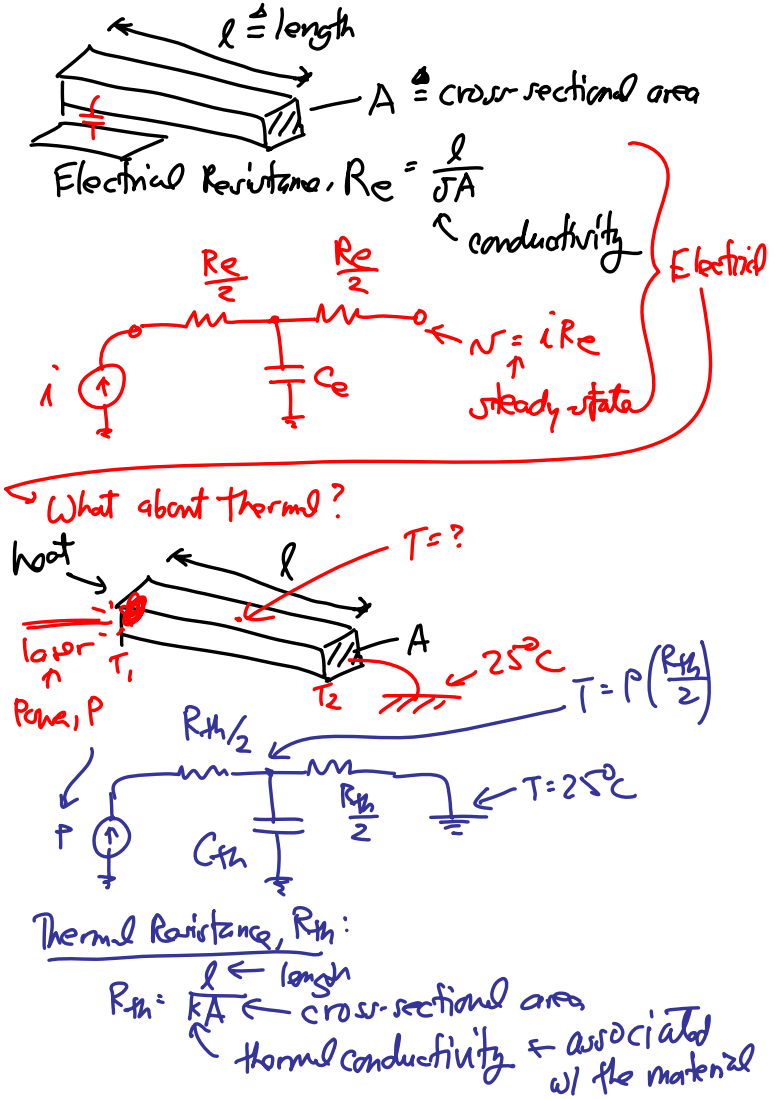
Still increases w/ smaller dims, although more slowly

④ Better Solution: other geometries



- HW#1 distributed today
- Go through Lecture Module 2, slides 6-26

Thermal Ckt. Modeling



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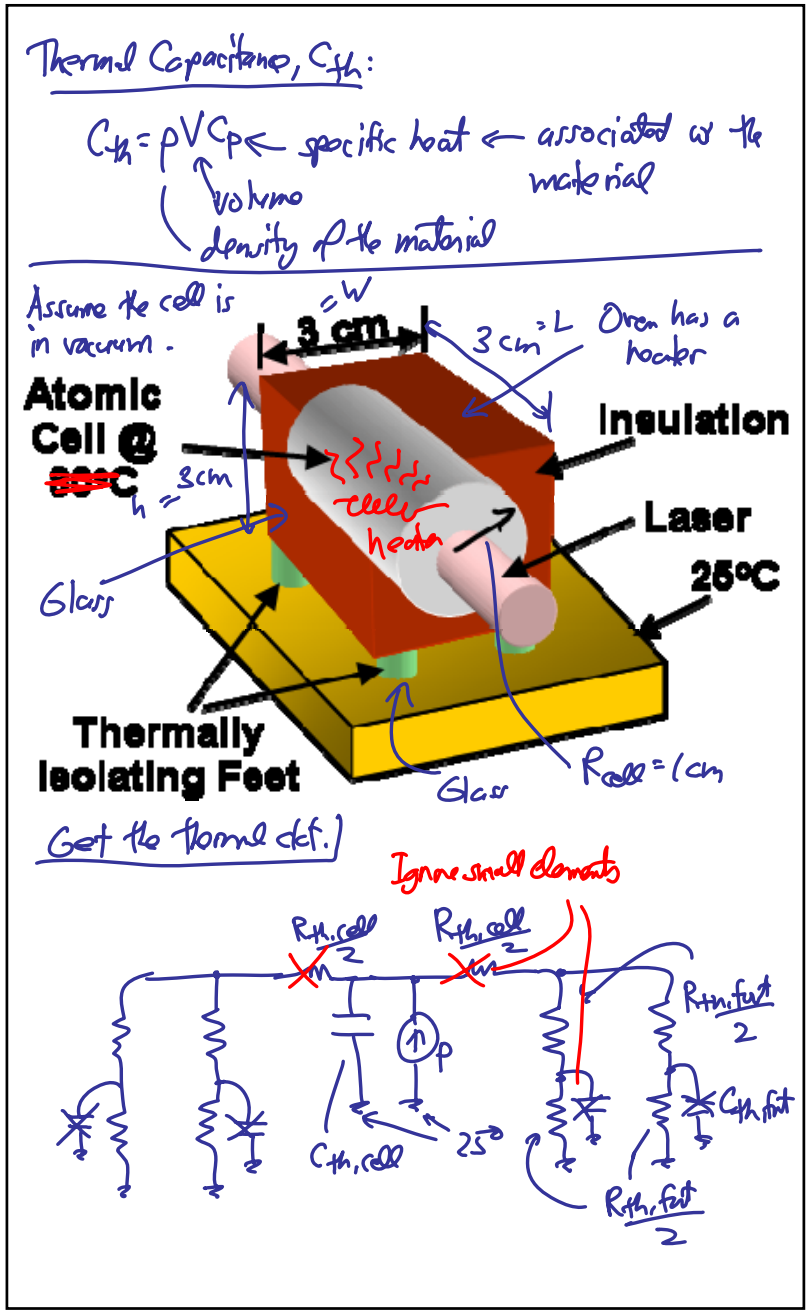

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