Lecture 3: Benefits of Scaling II

- Announcements:
- Make-up lecture:
  - Trying for this Friday afternoon
- Change Discussion Section time?
  - M 2-3 is one candidate ✗
  - ~~M 3-4?~~
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- Today:
- Reading: Senturia, Chapter 1
- Lecture Topics:
  - Benefits of Miniaturization
  - Examples
    - —GHz micromechanical resonators
    - —Chip-scale atomic clock
    - —Thermal Circuits
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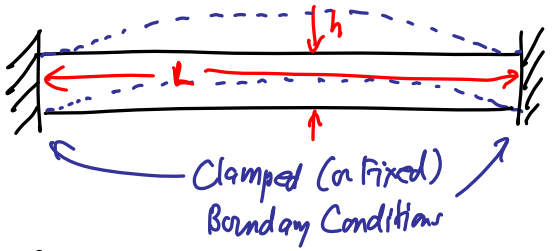
- Last Time: Going through module 2



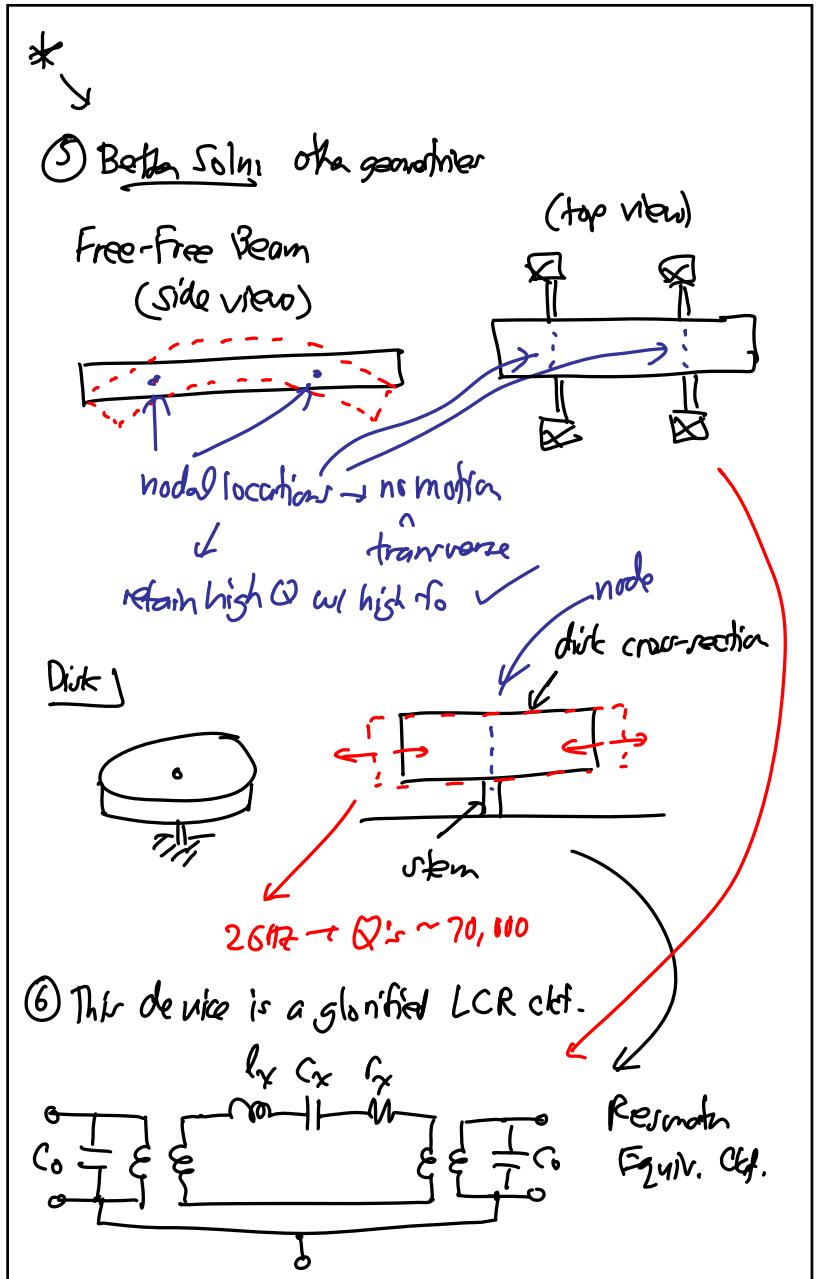
⇒ Eq. for resonance:

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

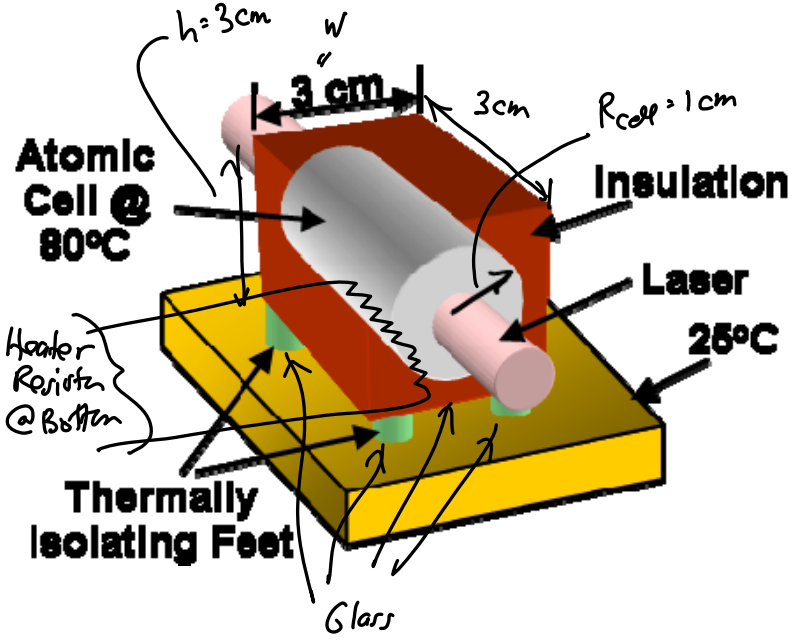
↓L → ↑f

where E ≙ Young's modulus [GPa] h ≙ thickness [m]

ρ ≙ density [kg/m³] L ≙ length [m]

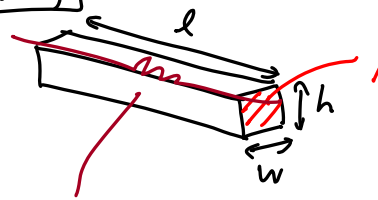


Example. Thermal Clot.
⇒ determine the power needed to get this atomic cell to 80°C (from RT) & how fast



First, Review Electrical Resistance

Resistance

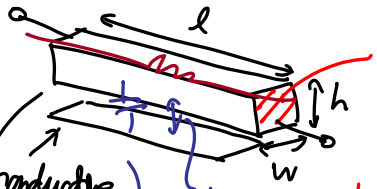


A ≙ cross-sectional area

R ≙ electrical resistance = $\frac{l}{\sigma A}$

↑ electrical conductivity

Capacitance



A ≙ cross-sectional area

conducting plate

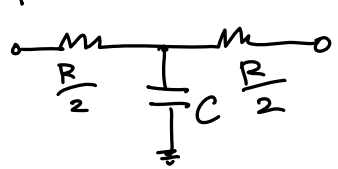
d

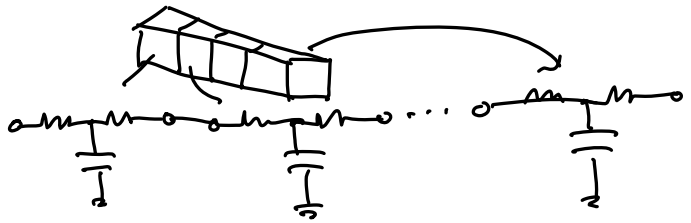
stores charge energy

C ≙ capacitance : $\frac{\varepsilon_0 W l}{d}$

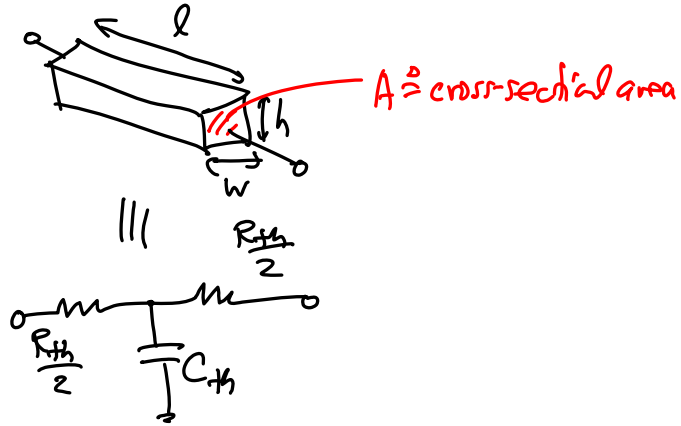
$E = \frac{1}{2}CV^2$

↑ voltage across capacitor





Thermal Ckt.



⇒ thermal capacitance: $C_{th} = \rho V C_p$ ← specific heat
density, volume → stores thermal energy

⇒ thermal resistance:

$R_{th} = \frac{l}{kA}$ ← length, ← cross-sectional area, ↑ thermal conductivity