Lecture 4: Benefits of Scaling III

- Announcements:
- Make-up lecture (for last Thursday): Friday, 3-4:30 p.m., 521 Cory
- Problem 3 of HW#1:
  - Assume the slab is the same material as the beams, i.e., it's not silicon
  - Also, treat the layer called "isolation layer" as thermal ground
  - Ta office hours: 367 cory
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- Today:
- Reading: Senturia, Chapter 1
- Lecture Topics:
  - Benefits of Miniaturization
  - Examples
    - —GHz micromechanical resonators
    - —Chip-scale atomic clock
    - —Thermal Circuits
    - —Micro gas chromatograph
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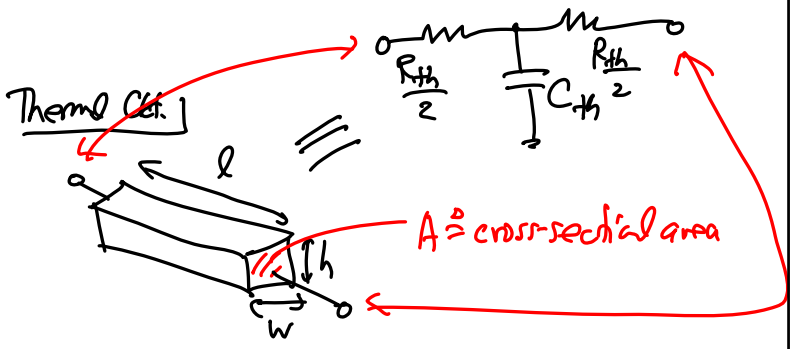
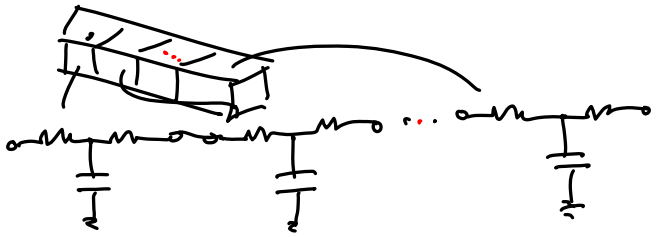
- Last Time: Covering thermal circuit modeling … which we now continue …



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

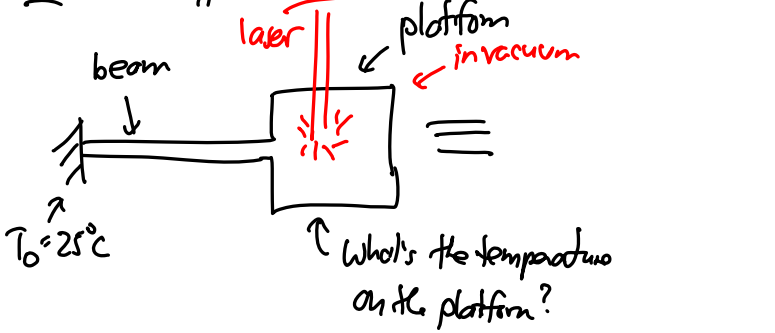
⇒ thermal resistance:

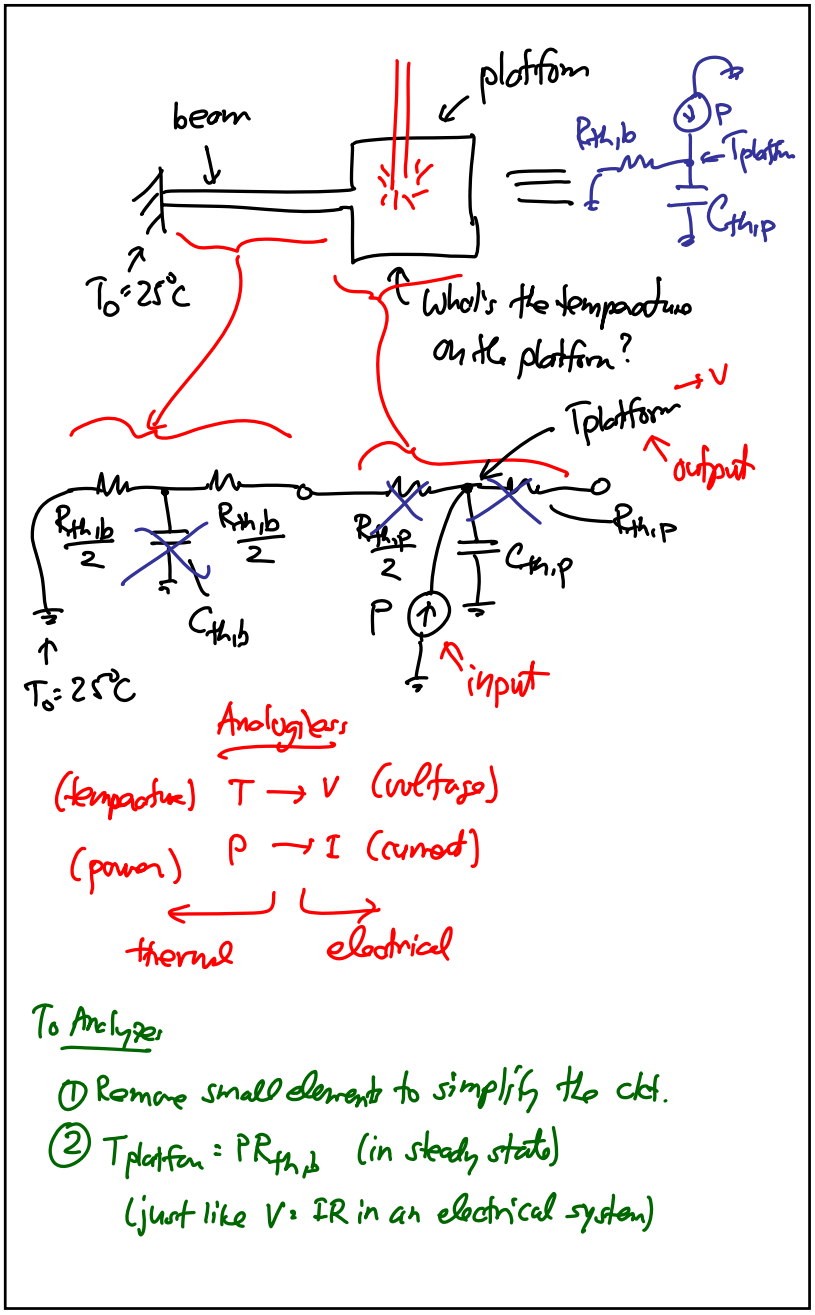
$R_{th} = \frac{l}{kA}$ ← length, ← cross-sectional area, ↑ thermal conductivity

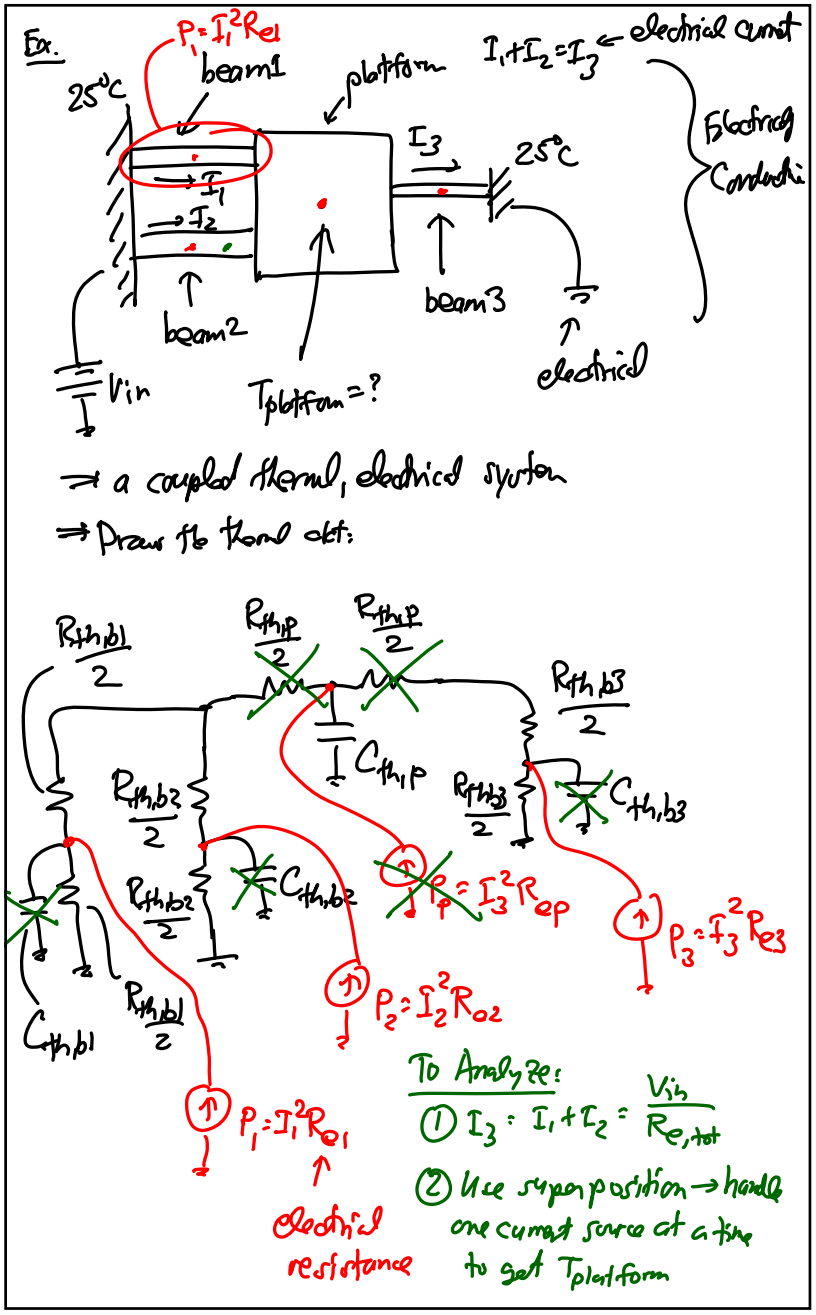


Examples

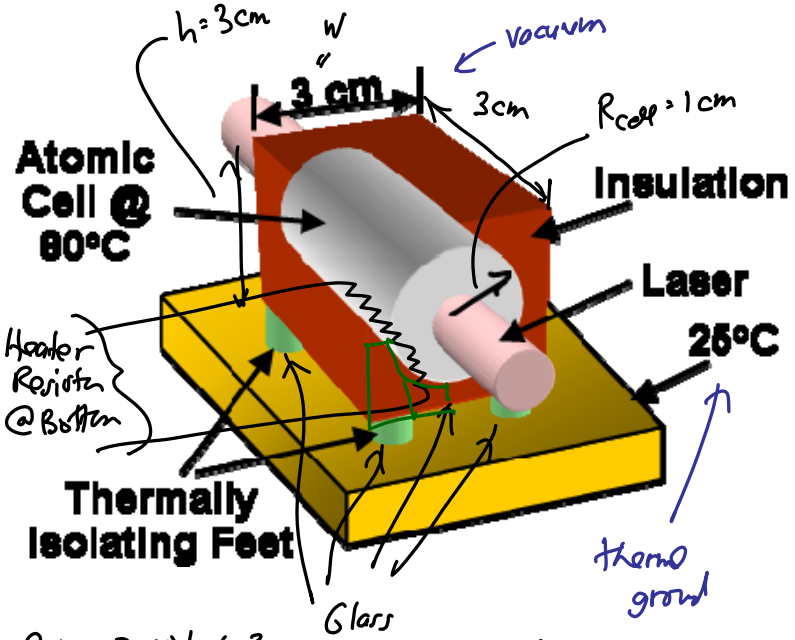
Ex. MEMS-type structure







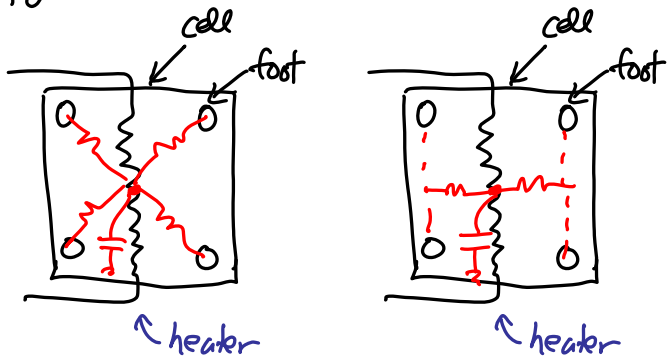
Example. Thermal Clot.
⇒ determine the power needed to get this atomic cell to 80°C (from RT) & how fast

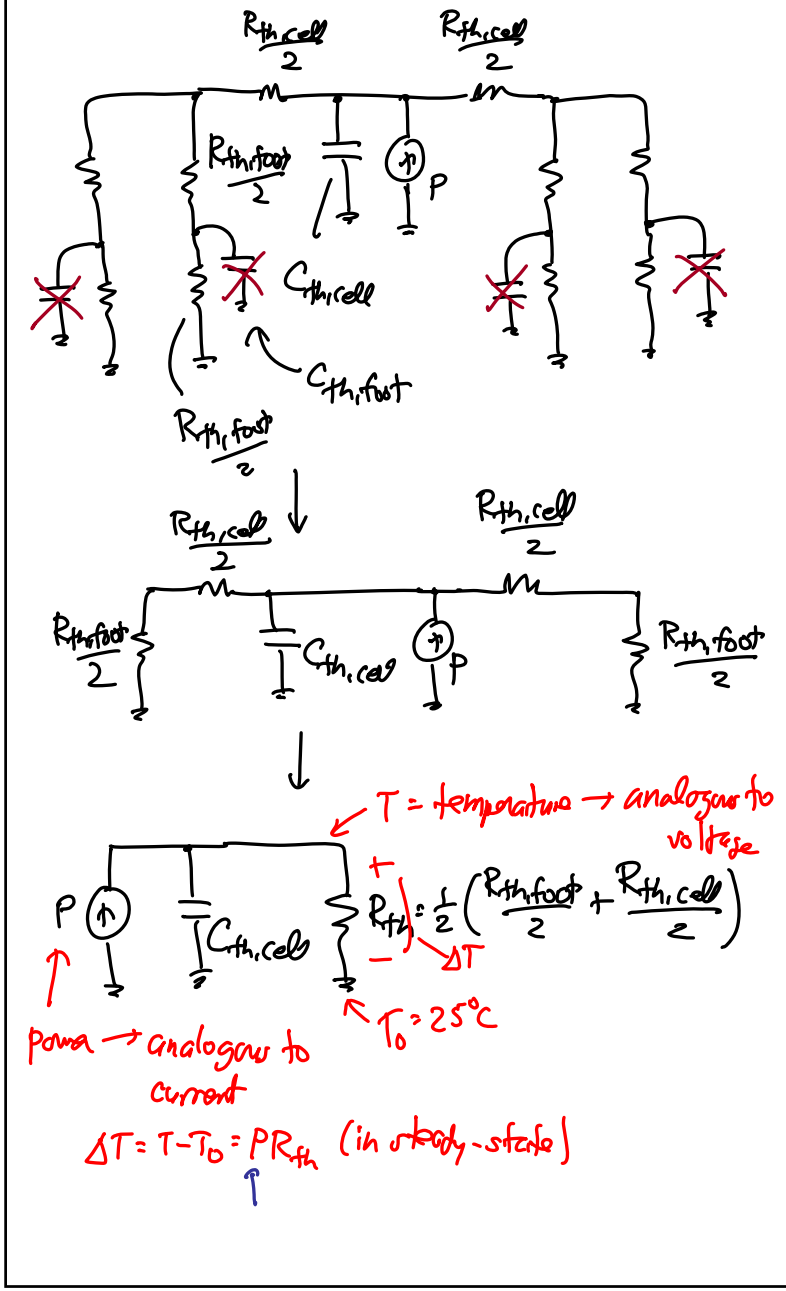


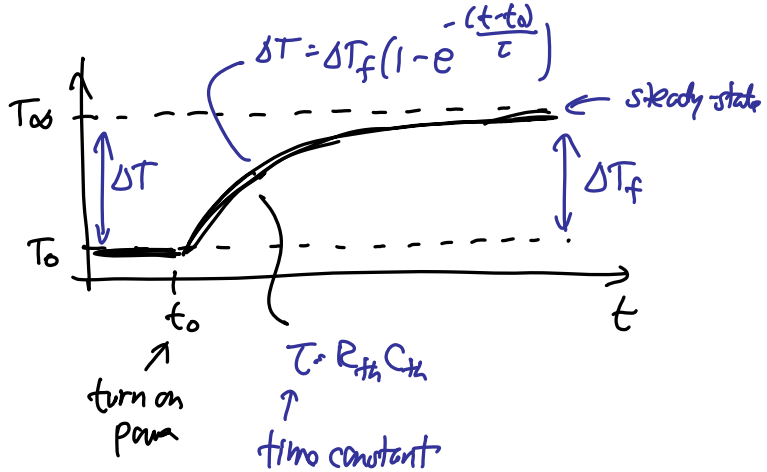
$\rho_{glass} = 2500\ kg/m^3$

$C_{p,glass} = 0.5\ J/(g \cdot K)$

$k_{glass} = 1.05\ \frac{W}{m \cdot K}$

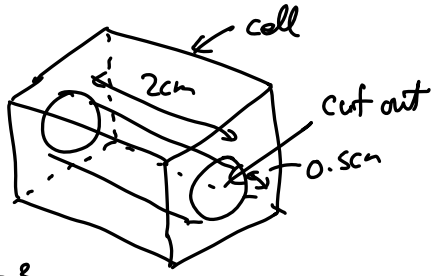






Find $C_{th,cell}$:

First, find the cell volume:



$V_{cell} = hWL - \pi R_{cell}^2 L$

$= (3cm)(3cm)(3cm) - \pi(1cm)^2(2cm) = 20.7 cm^3$

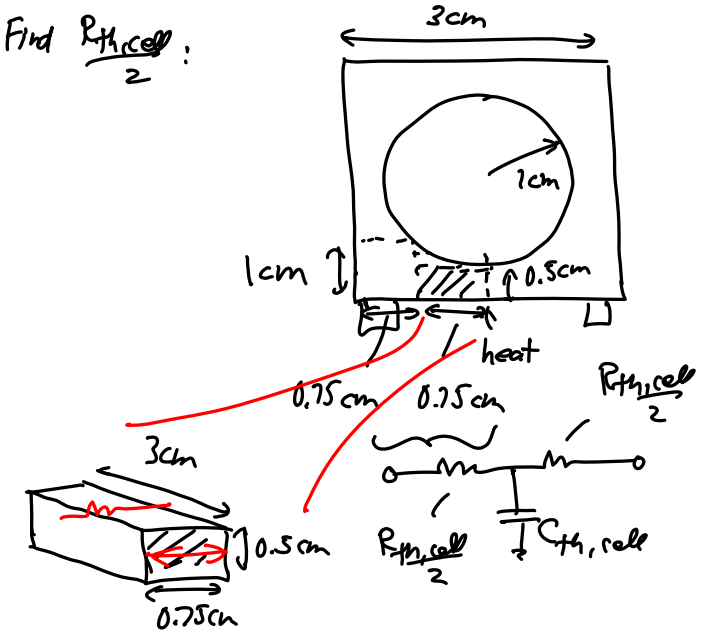
$C_{th,cell} = \rho_{glass} V_{cell} C_{p,glass}$

$= \left(2500 \frac{kg}{m^3}\right)\left(1000 \frac{J}{kg}\right)\left(\frac{1}{100^3}\frac{m^3}{cm^3}\right)$

$\times (20.7 cm^3)\left(0.5 \frac{J}{g \cdot K}\right)$

$\Rightarrow C_{th,cell} = 25.9 J/K$

Find $\frac{R_{th,cell}}{2}$:



$\frac{R_{th,cell}}{2} = \frac{\frac{3}{4}}{k(3)(\frac{1}{2})} + \frac{\frac{3}{4}}{k(3)(1)} = \frac{1}{k}\left(\frac{1}{8} + \frac{1}{4}\right) = \frac{3}{8}\frac{1}{k}$

$\left[R_{th} = \frac{l}{kA}\right] \quad \therefore \frac{R_{th,cell}}{2} = \frac{3}{8}\frac{1}{1.05} \times \left(100 \frac{cm}{m}\right) = \underline{35.7 K/W}$