PROBLEM SET #1

Issued: Tuesday, January 31, 2017

Due: Tuesday, February 14, 2017, 10:00 a.m. in the EE C247B homework box near 125 Cory.

1. Fig. PS1.1 below presents the perspective view of a cube suspended above the substrate by folded flexures at the inner points indicated. The entire structure, including cube and all suspensions, is perfectly symmetric and constructed of a single structural material. For this problem, assume that the cube and all folding trusses are rigid in all directions, including the vertical (i.e., *z*) direction. For simplicity, ignore gravity in this problem.

Use the following scaling convention: For a reduction, the scaling factor is less than one, i.e., for a quantity that has become 2x smaller, the scaling factor is 0.5x. Likewise, for an increase, the scaling factor is greater than one.

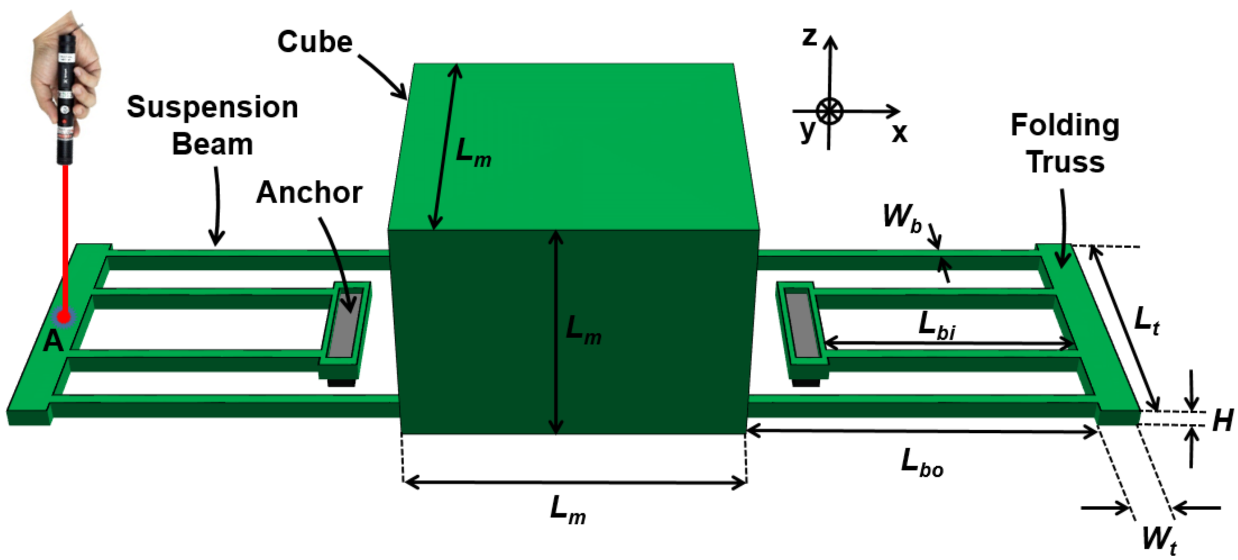

Fig. PS1.1

Answer the following questions:

(a) If all structural dimensions were scaled by 0.01x, by what factor would the thermal time-constant of the structure change?

(b) Suppose a laser is directed at point A to deliver a power P_i to that location that achieves a temperature T_m on the cube. If all structural dimensions were scaled by 0.01x, by what factor would the input laser power need to be adjusted in order to maintain the same temperature T_m on the cube while still directed at point A?

2. Suppose a step-function voltage V_A were suddenly applied across the anchors of a 2μm-thick polysilicon folded-beam suspended structure as shown in the figure below. All parameters are given in Table PS1.1. Ignore the thermal and electrical resistance of the shuttle.

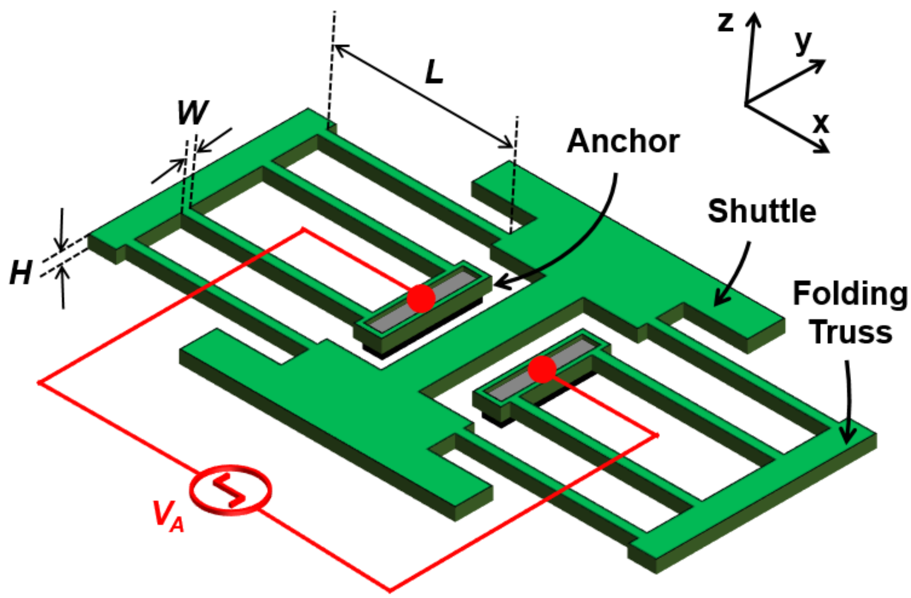

Fig. PS1.2

PARAMETER	VALUE	UNIT
Young's Modulus, *E*	150	GPa
Density, *ρ*	2,300	kg/m^3
Poisson Ratio, *v*	0.226	-
Sheet Resistance, R_s	10	Ω/□
Specific Heat, c_p	770	J/kg.K
Thermal Conductivity, *k*	30	W/m.K
Beam Length/Width/Thickness, *L*/*W*/*H*	50/2/2	μm/μm/μm
Folding Truss Area, A_f	250	μm^2
Shuttle Area, A_s	8,000	μm^2

Table PS1.1

Answer the following questions:

(a) With what time-constant will the shuttle reach its steady-state temperature after the voltage V_A steps from 0V to 1V? Give a formula and numerical answer with units.

(b) If the final step function value of V_A is 1V, what is the steady-state temperature on the shuttle? Give a formula and numerical answer with units.

3. This problem concerns the micro-atomic cell summarized in Fig. PS1.3, with all relevant dimensions and materials indicated, and with material properties summarized in the Table PS1.2

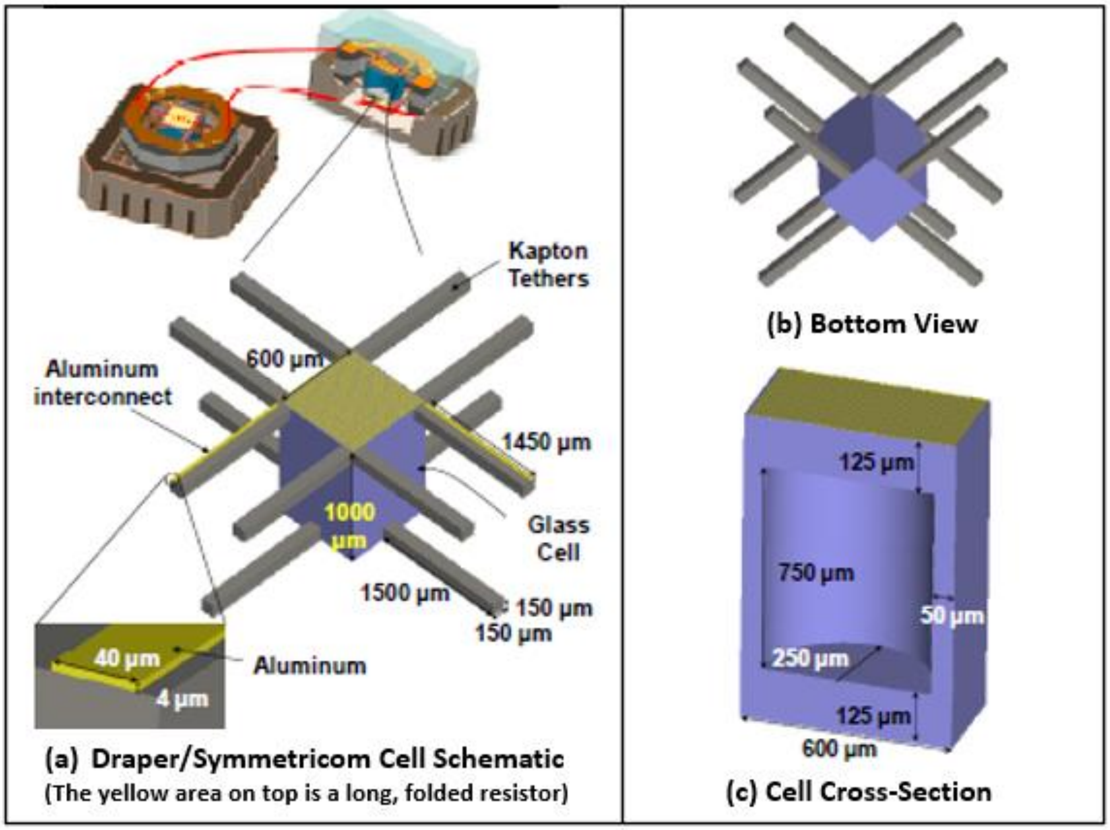

Fig. PS1.3

PARAMETER	GLASS	ALUMINUM	KAPTON	UNIT
Density, *ρ*	2,500	2,700	1,420	kg/m^3
Thermal Conductivity, *k*	1.05	136	0.12	W/m.K
Specific Heat, c_p	500	903	755	J/kg.K

Table PS1.2

Answer the following questions:

(a) Determine the power required to maintain a cell temperature of 80°C if the cell itself operates under a vacuum environment.

(b) Determine the warm-up time (i.e., the time constant) of the system. In other words, what is the time constant with which the temperature rises when a step function in input power is applied to the system?