PROBLEM SET #1

Issued: Tuesday, January 28, 2020

Due: Tuesday, February 11, 2020 at 8:00 a.m. via Gradescope.

1. Figure PS1.1 below presents the perspective view of a micromechanical device constructed in a 3 μm-thick structural layer and suspended above the substrate by double folded-flexure support beams, with anchors to the substrate at the points indicated. The entire structure, including the mass and all its supports, consists of a single structural material. Table PS1.1 lists some useful material properties and structural dimensions. For this problem, assume that the mass and all folding trusses are rigid in all directions, including the vertical (i.e., z) direction, and ignore gravity for simplicity. You may also assume that the structure is operating in vacuum and the substrate temperature is 25°C.

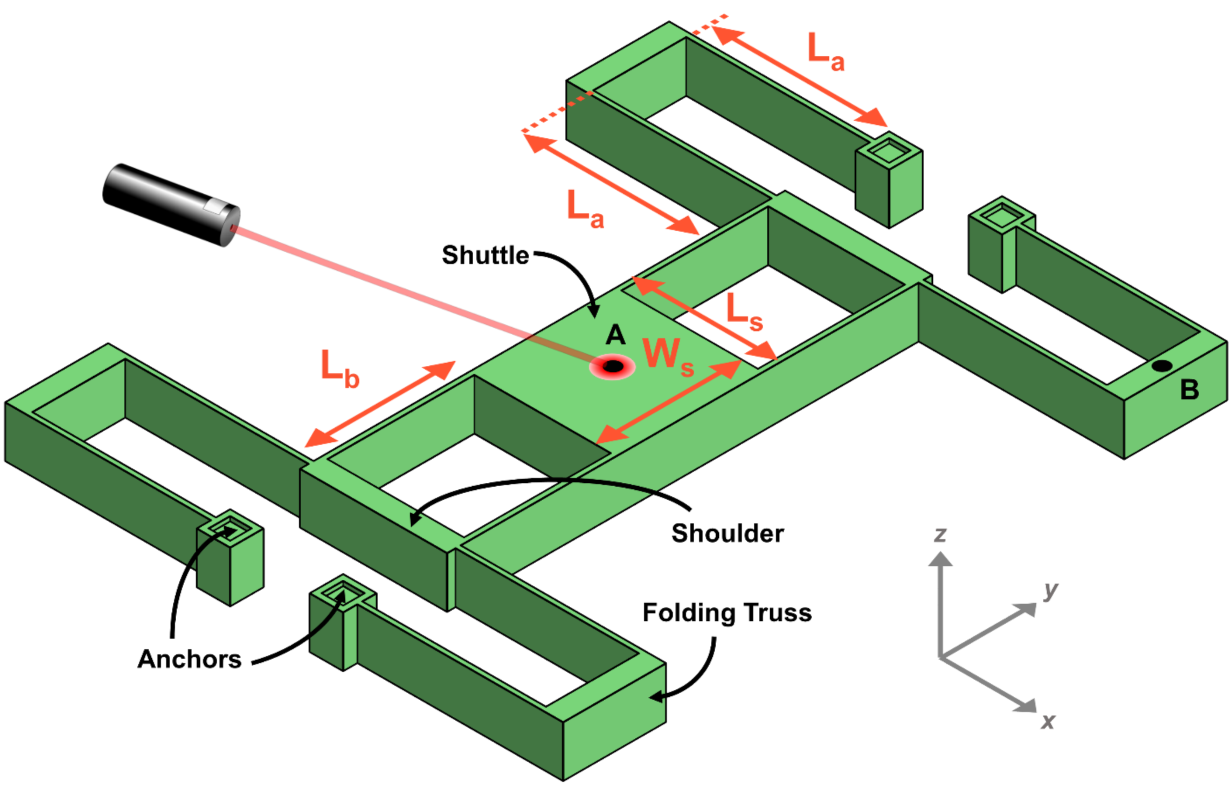

Figure PS1.1

PARAMETER	***VALUE***	***UNIT***
Young's Modulus, E	150	GPa
Density, ρ	2,300	kg/m^3
Poisson's Ratio, v	0.226	-
Specific Heat, c_p	700	J/(kg·K)
Thermal Conductivity, k	90	W/(m·K)
Beam Width, W_b	1	µm
Beam Lengths, L_a / L_b	95 / 120	µm / µm
Shuttle Width, W_s	100	µm
Shuttle Length, L_s	100	µm
Structural Layer Thickness, t	3	µm

Table PS1.1

(a) Suppose a laser aimed at point A on the structure as indicated delivers a power of 1 mW to the very center of the shuttle mass. Find the steady-state temperature $T_{B,SS}$ at point B on the structure.

(b) Find the thermal time constant τ_{th} at point A on the structure.

(c) Assuming the laser turns on instantaneously at $t = 0$, find the time it takes for the temperature at point A, $T_A(t)$ to reach 150ºC.

(d) Now assume that all physical dimensions are scaled by a scaling factor S. Find the laser power P_{in} required to maintain the same steady-state temperature $T_{B,SS}$ found in part (a), as well as the new time to 150ºC for $T_A(t)$ (assuming this new input power) for:

i. $S = 25$

ii. $S = 0.75$

iii. $S = 1 \times 10^{-3}$

Note: Use the scaling convention where $S > 1$ indicates an increase in size and $S < 1$ indicates a reduction in size. E.g., for a scaling factor of 0.25, all dimensions would become 4 times smaller.

2. This problem intends to jog your memory of op amp circuit analysis, which some of you might not have done for ages. We will not actually be using op amps seriously in the course until about the 10th week, so if you have forgotten them, here is your chance to start remembering. When considering the op amp circuit in Figure PS1.2, assume the op amp is ideal.

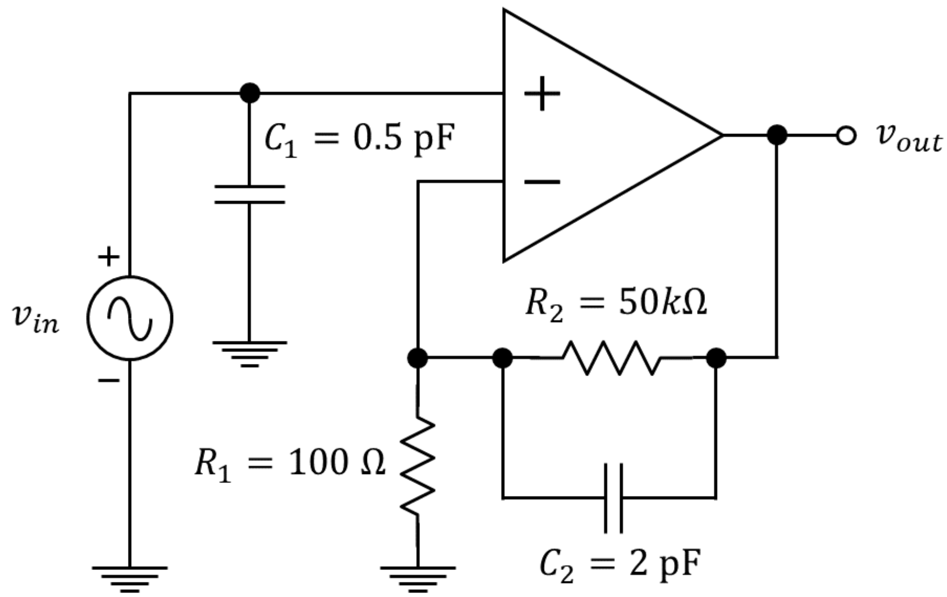

Figure PS1.2

(a) Find the transfer function of the amplifier, $H(s) = \frac{v_{out}(s)}{v_{in}(s)}$ in terms of R_1, R_2, C_1 & C_2.

(b) How does $H(s)$ depend on C_1? Why might this be considered beneficial when sensing signals from MEMS devices?

(c) Sketch the Bode plot of the amplifier response (magnitude and phase) for the given values of R_1, R_2, C_1 & C_2. Make sure to indicate clearly the DC gain of the amplifier as well as the 3dB cutoff frequency.