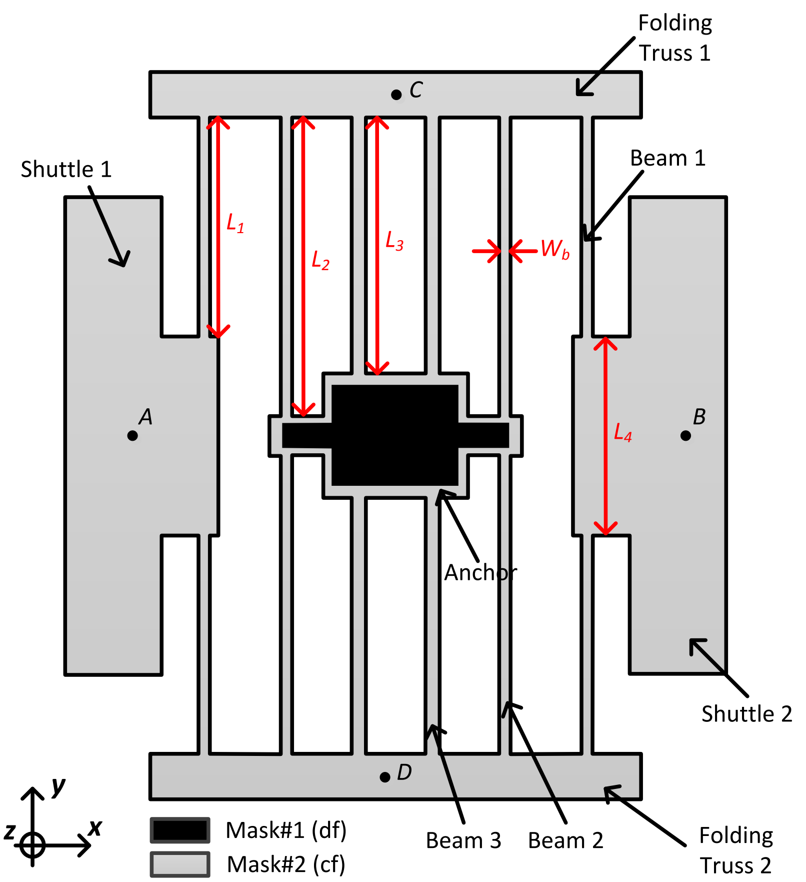
PROBLEM SET #5

Issued: Tuesday, Oct. 16, 2012

Due (at 7 p.m.): Tuesday Oct. 23, 2012, in the EE C245 HW box near 125 Cory.

1. The figure below presents the top view of a micromachined device fabricated in a 3μm-thick structural layer. Here, everything is suspended 2μm above the substrate except for the anchor location indicated as the darkly shaded region. Data on the structural material used in this problem and specific geometric dimensions are given in the box beside the figure. Also, assume that all folding trusses and shuttles are rigid in all directions, including the vertical (i.e. *z*) direction.



<u>Structural Material Properties</u>:

Young's Modulus, E = 150 GPa;
Density, ρ = 2,300 kg/m^3;
Poisson ratio, ν = 0.226
DI Water Contact Angle for Structural and Substrate Materials: 85^o
Water-Air Interface Surface Tension: 72.75×10^{-3} N/m

<u>Structural Dimensions</u>:

L_1 = 100μm; L_2 = 150μm
L_3 = 120μm; L_4 = 120μm
W_b = 2μm
$A_{Truss1} = A_{Truss2}$ = 800μm^2
$A_{Shuttle1} = A_{Shuttle2}$ = 2900μm^2

Figure PS5.1

(a) Write expressions for the stiffness of beams 1, 2, 3 and calculate the numerical values.

(b) Write an expression for the stiffness at point *A*.

(c) If point *C* moves $x_C = 1$μm in the *x*-direction due to a force applied at *A*, how much does point *B* move? Provide an expression for x_B in terms of x_C and spring constants, and calculate a numerical value.

(d) Write an expression for the stiffness at point *C*.

(e) Assume the fracture stress of silicon is 7GPa. How much can point *C* move due to a force applied at *C*, right before any fracture happens in the structure? Explicitly point out where this fracture happens.

(f) Suppose the structure is released using liquid HF, then rinsed in DI water. Will the released structure be stuck to the substrate after drying? Note that the stiction forces at the shuttles and trusses depend on the gap spacing at those locations, which may not be the same. Assume you can ignore stiction forces applied to the beams.

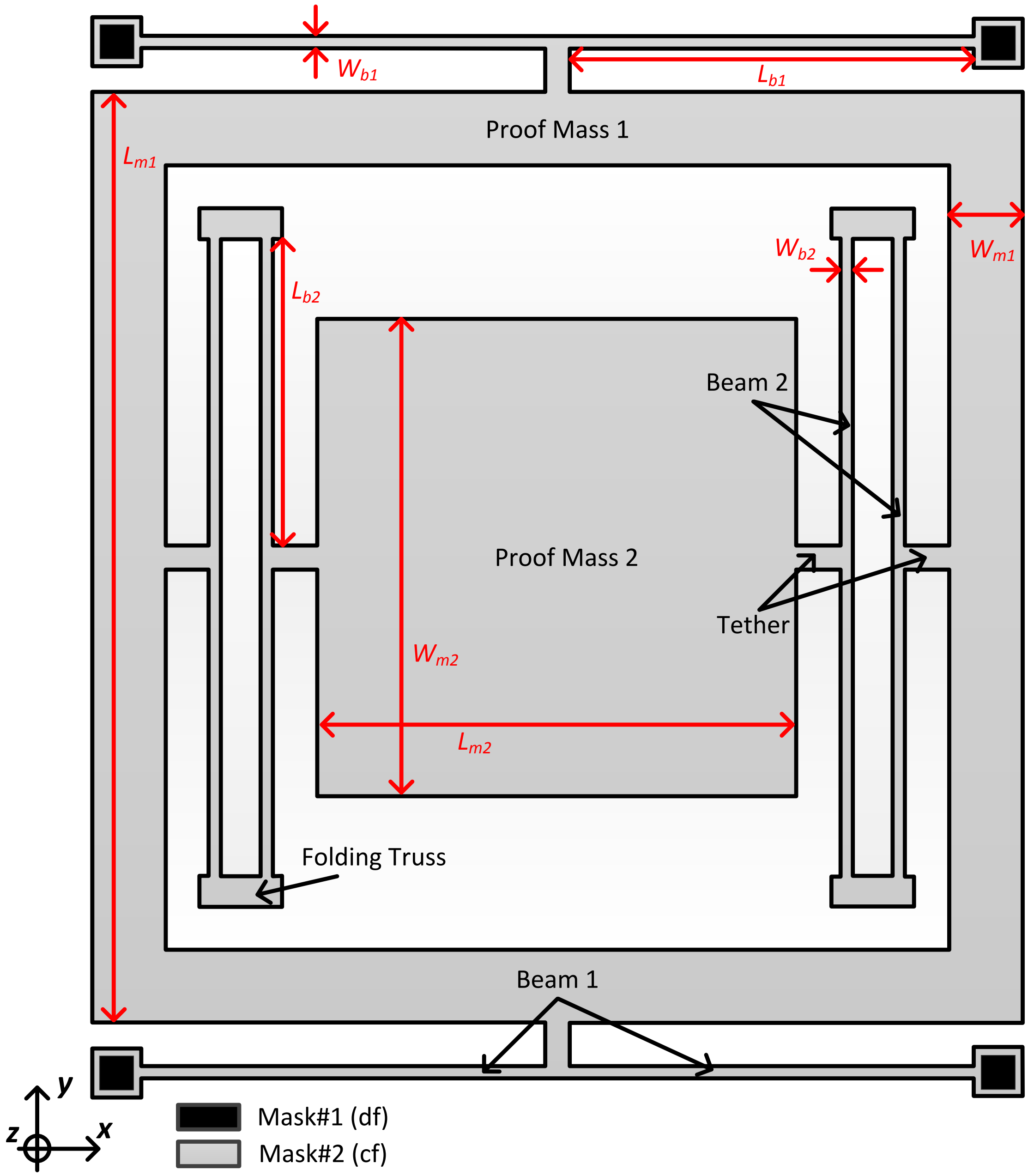
2. Figure PS5.2 presents the top view of a 3μm-thick gyroscope structure designed to measure rotation around the *z*-axis. (Note that you need not understand how a gyroscope works to do this problem.) Data on the structural material used in this problem and specific geometrical dimensions are given in the box below. Also, assume that all proof masses, trusses and tethers are perfectly rigid in all directions, including the vertical (i.e. *z*) direction.

(a) Write expressions for the stiffness of beams 1 and 2 and calculate the numerical values.

(b) Write an expression for the stiffness at proof mass 1 in the *x*-, *y*- and *z*-directions in terms of beam stiffnesses, and calculate numerical values.

(c) Write an expression for the stiffness at proof mass 2 in the *x*-, *y*- and *z*-directions in terms of beam stiffnessess, and calculate numerical values.

(d) How much does proof mass 2 move when structure experiences a 10g constant acceleration in *y*-direction? What is the maximum bending stress in the structure due to this constant acceleration and where does this maximum happen?



<u>Structural Material Properties</u>:
Young's Modulus, E = 150 GPa; Density, ρ = 2,300 kg/m^3; Poisson ratio, ν = 0.226;

<u>Structural Dimensions</u>:
L_{b1} = 180µm; W_{b1} = 2µm; L_{b2} = 150µm; W_{b2} = 2µm;
L_{m1} = 400µm; W_{m1} = 10µm; L_{m2}= 250µm; W_{m2} = 250µm;

Figure PS5.2