Problem Set #3: Solutions

1. Cross-section after step iv):

```
    Si
   SiO₂
  substrate
```

Cross-section after step vii):

```
    SiₙNₘ
  Si
   SiO₂
  substrate
```

Final cross-section:

```
    SiₙNₘ
  Si
   SiO₂
  substrate
```

```
    10 μm
    ↓
  Si
   Si
```

```
   1 μm
  Si
   Si
```

```
    2 μm
   SIO₂
```

```
    1 μm
  substrate
```
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Before step 11.0

\[ A - A^0 \]
A misalignment of 3 μm would cause the support beams on the left side to be longer than those on the right. This will increase energy dissipation to the substrate and lower the device’s Q. If the misalignment was more severe, the already etched nitride could be completely removed, exposing the isolation oxide & (after release) the substrate.

\[
k_z = \sum_{i=1}^{n} E W_i \left( \frac{H_i}{L_i} \right)^3 = 4 E W_b \left( \frac{H_b}{L_b} \right)^3 = 4 \left( 150 \text{ GPa} \right) \left( 2 \mu \text{m} \right) \left( \frac{2 \mu \text{m}}{40} \right)^3 = 150 \text{ N/m}
\]

At equilibrium:

\[
F_{st} = F_{sp}
\]

\[
\frac{2 \gamma_{lc} \cos \Theta_c}{(d_o - z)} = k_z \cdot z
\]

\[
k_z z^2 - k_z d_o z + 2 \gamma_{lc} \cos \Theta_c = 0
\]

In order for the beam to not be stuck, there must exist a real sol’n for \( z \)

i.e.:

\[
B^2 - 4AC > 0 \quad \text{(quadratic formula)}
\]

\[
(k_z d_o)^2 - 4(k_z) \left( 2A y_{lc} \cos \Theta_c \right) > 0
\]

\[
(150 \cdot 2 \mu \text{m})^2 - 4(150)(2 \cdot 460 \mu \text{m}^2 \cdot 72.75 \text{ N/m} \cdot \cos(30)) = 5.522 \times 10^{-3} > 0
\]

Beam won’t be stuck!

(d) Set discriminant = 0 & solve for \( d_o \)

\[
(k_z d_o, \text{min})^2 - 4(k_z) \left( 2A y_{lc} \cos \Theta_c \right) = 0 \Rightarrow d_{o, \text{min}} = \frac{\sqrt{8A y_{lc} \cos \Theta_c}}{k_z} = 1.243 \mu \text{m}
\]

The beam will be stuck if the sacrificial PSG layer is thinner than 1.243 μm.