1.0 Define Inputs

- \( b := 62.5 \text{mm} \) Side of module
- \( a_1 := 2 \cdot (28.14 \text{mm}) \) Distance between tension rods
- \( a_2 := 2 \cdot (56.25 \text{mm}) \)
- \( n_L := 194 \) Number of layers of lead
- \( n_s := 194 \) Number of layers of scintillator
- \( t_L := 0.5 \text{mm} \) Thickness of lead
- \( t_s := 1.5 \text{mm} \) Thickness of scintillator
- \( t_{\text{gap}} := 0.24 \text{mm} \) Thickness of gap
\[ \rho_L := 0.011340 \, \frac{\text{kg}}{\text{cm}^3} \]  
Density of lead

\[ E_L := 2560 \, \text{ksi} \]  
Modulus of lead

\[ \rho_s := 0.001220 \, \frac{\text{kg}}{\text{cm}^3} \]  
Density of scintillator

\[ E_s := 460 \, \text{ksi} \]  
Modulus of scintillator

\[ \mu := 0.1 \]  
Coefficient of friction between layers

\[ D_{\text{rod}} := 2.5 \, \text{mm} \]  
Diameter of rods

\[ F_y := 18000 \, \text{psi} \]  
Yield strength of brass rods

\[ E_{\text{brass}} := 15000 \, \text{ksi} \]  
Modulus of brass

\[ E_{\text{steel}} := 30000 \, \text{ksi} \]  
Modulus of steel

2.0 Calculate Properties of Calorimeter

Length := \( n_L t_L + n_s t_s = 388.00 \, \text{mm} \)

Length = 15.28 \, \text{in}

Area := 100 \, \text{cm}^2

Weight := \( n_L g \rho_L \cdot \text{Area} \cdot t_L + n_s g \rho_s \cdot \text{Area} \cdot t_s \)

Weight = 32.1 \, \text{lbf}

Weight = 142.7 \, \text{N}

\[ q := \frac{\text{Weight}}{\text{Length}} \]

\[ q = 2.10 \, \frac{\text{lbf}}{\text{in}} \]

\[ A_{\text{rod}} := \frac{\pi \cdot D_{\text{rod}}^2}{4} \]
\[ \Lambda_{\text{rod}} = 0.01 - \text{in}^2 \]

### 3.0 Pre-Loading

Assume a pre-load is applied to the stack and then four threaded rods are snugged to the stack and then the pre-load is released.

\[ F_{\text{preload}} := 500 \text{kg} \cdot g = 1102.31 \text{ lbf} \]

\[ k_{\text{BrassRod}} := \frac{6 \Lambda_{\text{rod}} E_{\text{brass}}}{\text{Length}} = 44827.75 \text{ lbf/in} \]

\[ k_{\text{SteelRod}} := \frac{6 \Lambda_{\text{rod}} E_{\text{steel}}}{\text{Length}} = 89655.51 \text{ lbf/in} \]

\[ k_{\text{stack}} := \left( \frac{n_s t_s}{\text{Area} \cdot E_s} + \frac{n_L t_L}{\text{Area} \cdot E_L} \right)^{-1} = 587175.52 \text{ lbf/in} \]

\[ \Delta_{\text{stack}} := \frac{F_{\text{preload}}}{k_{\text{stack}}} = 0.001877 \text{ in} \]

\[ \Delta_{\text{rod}} := \frac{\Delta_{\text{stack}} \cdot k_{\text{stack}}}{k_{\text{BrassRod}} + k_{\text{stack}}} = 0.00174 \text{ in} \]

\[ F_{\text{rod}} := \Delta_{\text{rod}} k_{\text{BrassRod}} = 78.19 \text{ lbf} \]  
Preload in rods due to initial applied load on stack

\[ N_{\text{req}} := \frac{\text{Weight}}{\mu} = 320.77 \text{ lbf} \]  
Required normal force to carry the load in friction

Use a preload on the rods that is twice the required value for safety factor

\[ N_{\text{preload}} := 2 \cdot N_{\text{req}} = 641.55 \text{ lbf} \]

\[ \Delta_{\text{rodN}} := \frac{N_{\text{preload}}}{k_{\text{BrassRod}}} = 0.014 \text{ in} \]
σ_{rod} := \frac{N_{preload}}{6\cdot A_{rod}} = 14053.15 \text{ psi}

4.0 Calculate the increase in rod loading due to being cantilevered.

\[ F_{\text{cantilever}} := \frac{q\cdot \text{Length}^2}{a_2 + 2a_1\cdot \left(\frac{a_1}{a_2}\right)} = 73.73 \text{ lbf} \]

\[ F_{rod} := \frac{N_{preload}}{6} + F_{\text{cantilever}} = 180.65 \text{ lbf} \]

\[ \Delta_{rodN} := \frac{F_{rod}}{k_{\text{BrassRod}}} = 0.004 \text{ in} \]

\[ \sigma_{rod} := \frac{F_{rod}}{6\cdot A_{rod}} = 3957.21 \text{ psi} \]

\[ \sigma_{\text{scintillator}} := \frac{F_{rod}}{\text{Area}} = 11.65 \text{ psi} \]  
Tensile stress in rods

\[ \tau_{rod} := \frac{F_{rod}}{\pi\cdot D_{rod}\cdot \frac{3}{32} \text{ in}} = 6231.82 \text{ psi} \]  
Shear stress in threads

Brass tensile yield strength of 18000 psi and the shear yield strength of the threads is 9000 psi so both stresses are ok