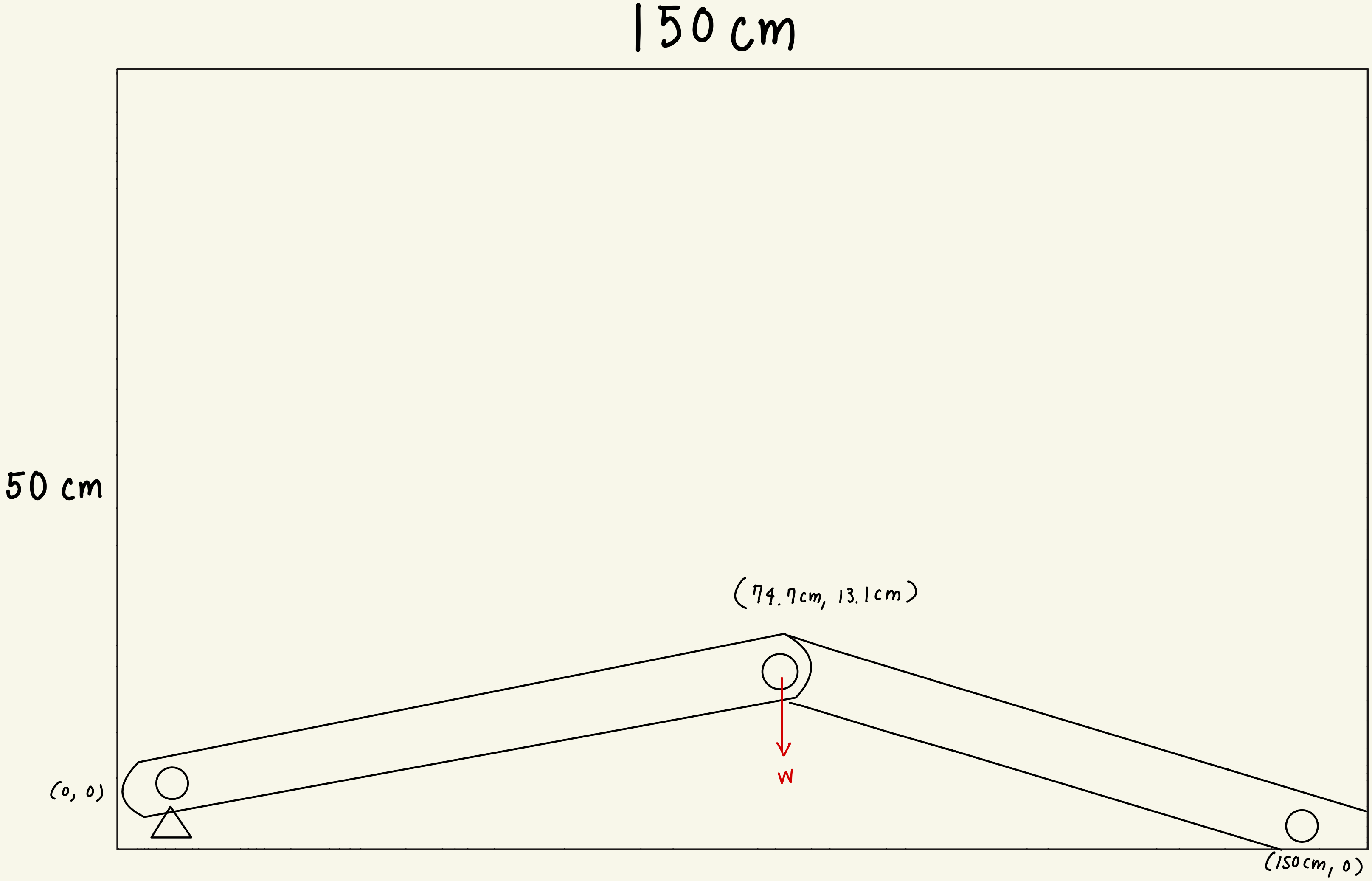


$X_{joint} = \sqrt{(75cm)^2 - (6.57cm)^2} = 74.7cm \longrightarrow$ pivot pin = (74.73, 13.14 cm)

$L_{beam} = \sqrt{(74.7cm)^2 + (13.14cm)^2} = 75.8\ cm \longrightarrow$ Actuator length = 76.4 cm

2. a

weight lifted:

$P = W_{\perp} + F_{act,\perp} \approx 244\,200\ N + 13.7\ N = 244213.7\ N$

Bar angle:

$\theta_{bar} = \tan^{-1}\left(\frac{13.1}{74.7}\right) = 9.9°$

$W_{\perp} = W\cos(\theta_{bar}) = (244213.7\ N)\cos(9.9°) = 242212\ N$ $W_{\perp} = 242212\ N$

$F_{act} = 8050\ N$

Angle difference btwn actuator & bar is $\sim 0.1°$

$F_{act,\perp} = F_{act}\sin(0.1°) = (8050\ N)\sin(0.1) = 14\ N$ $\boxed{F_{act,\perp} \approx 13.7\ N}$

$P = W_{\perp} + F_{act,\perp} = 242{,}212N + 14N = 242212N$ $\boxed{P = 244{,}214N}$

$$\delta_{max} = \frac{PL^3}{3EI} = \frac{(2.44 \times 10^5 N)(0.758\ m)^3}{3EI} \longrightarrow \frac{(2.44 \times 10^5 N)(0.4355 m^3)}{3EI} = \frac{114205\ Nm^3}{3EI}$$

2.b

Shape: Hollow tube

Material: Aluminum

Let candidate tube be 40mm × 20mm × 2mm wall

$h_o = 0.04m$ $h_i = h_o - 2t = 0.04m - 0.004m = 0.034m$

$b_o = 0.02m$ $b_i = b_o - 2t = 0.02m - 0.004m = 0.016m$

$t = 0.002m$

moment of inertia:

$$I_o = \frac{b_o h_o^3 - b_i h_i^3}{12}$$

outer moment of inertia:

$$I_o = \frac{(0.02m) \times (0.04m)^3}{12} = 1.0\bar{6} \times 10^{-7} \ m^4$$

inner moment of inertia:

$$I_1 = \frac{(0.016m) \times (0.034m)^3}{12} = 6.2208 \times 10^{-8} m^4$$

$$I = I_o - I_i = (1.0\bar{6} \times 10^{-7} \ m^4) - (6.2208 \times 10^{-8} m^4) = 4.446 \times 10^{-8} m^4$$

$I = 4.446 \times 10^{-8} m^4$

From part 2a: $\delta_{max} = \dfrac{114205 Nm^3}{3EI}$

for aluminum: $E = 70 \ GPa$

$$\hookrightarrow \delta_{max} = \frac{114205 Nm^3}{(70 \times 10^9 \ Pa)(4.446 \times 10^{-8} m^4)} = 36.7m$$

$$\delta_{allow} = 0.02L = 0.02(0.78m) = 0.01516 m$$

$\delta_{allow} << \delta_{max} \longrightarrow$ This design fails.

Design 2:

1st find minimum required I

$$\delta_{max} \leq 0.02L \longrightarrow \delta_{max} = 0.02(0.758m) = 0.01516m$$

$$\delta_{max} = \frac{114205 Nm^3}{3EI}$$

$$\delta_{max} = \delta_{allow} \longrightarrow \frac{114205 Nm^3}{3EI} = 0.01516m$$

$$I = \frac{114205 Nm^3}{3E(0.01516m)}$$ let the material be aluminum $\longrightarrow E = 70GPa$

$$I = \frac{114205 Nm^3}{3(70 \times 10^9 pa)(0.01516m)} = 3.587 \times 10^{-5} \ m^4$$

candidate tube : 250 mm x 150mm x 10mm

$h_o = 0.25m$ $h_i = h_o - 2t = 0.23m$

$b_o = 0.15m$ $b_1 = b_o - 2t = 0.13m$

$t = 0.01m$

outer moment of inertia:

$$I_o = \frac{0.15m(0.25m)^3}{12} = 1.953 \times 10^{-4} m^4$$

inner moment of inertia:

$$I_i = \frac{(0.13m)(0.23m)^3}{12} = 1.138 \times 10^{-4} m^4$$

$$I = I_o - I_i = 1.953 \times 10^{-4} m^4 - 1.138 \times 10^{-4} m^4 = 6.35 \times 10^{-5} m^4$$

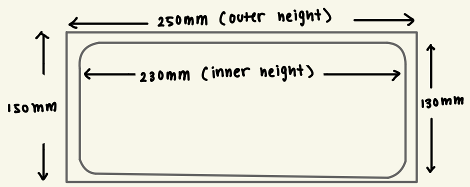
$$\delta_{max} = \frac{114205 Nm^3}{3EI} = \frac{119205 Nm^3}{3(200 \times 10^9 pa)(6.35 \times 10^{-5} m^4)} = 0.003m$$

$\delta_{allow} = 2L = 2(0.78m) = 0.01516m$ $\delta_{max} < \delta_{allow} \longrightarrow$ This beam satisfies deflection & is mass efficient for this stiffness level

Final Design choice : Hollow Aluminum tube w dimensions : 250mm x 150mm x 10mm

2.C

Final Beam Design cross-section: (Aluminum 6061-T6)



outer width: 150mm

wall thickness: 10mm

Material: Aluminum 6061-T6

Young's Modulus: 70 GPa

Computed Moment of Inertia: $6.35 \times 10^{-5} m^4$

Max deflection under load: 0.003 m