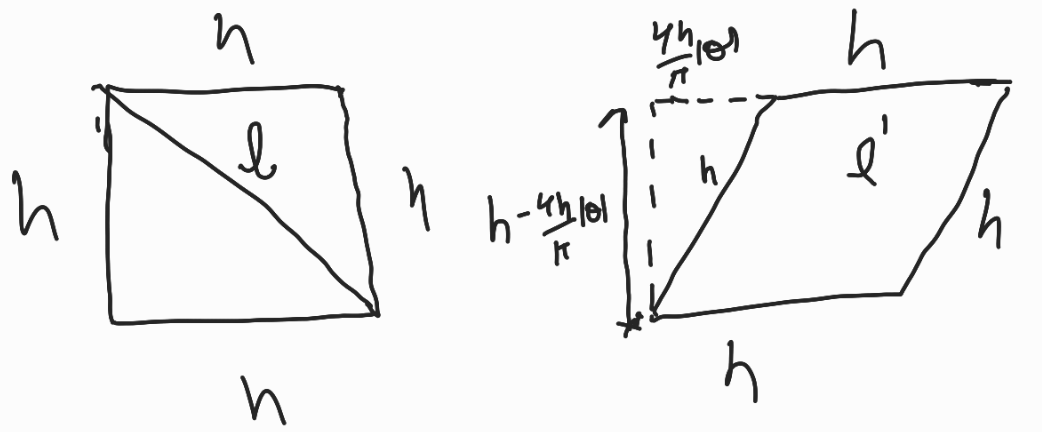
ϕ

$\Theta = k\phi$

$\phi_{desired}$ based on sunlight

$\Theta = K \Delta l$



$\theta = 0$ $\qquad$ $\theta = \theta$

$$h\left(1-\frac{4|\theta|}{\pi}\right)^2 + x^2 = h^2$$

$$h^2\left[1-\frac{8\theta}{\pi}\right] + x^2 = h^2$$

$$x^2 = \frac{8\theta}{\pi}h^2$$

$$x^2 + \frac{4^2h^2}{\pi}\theta^2 = h^2$$

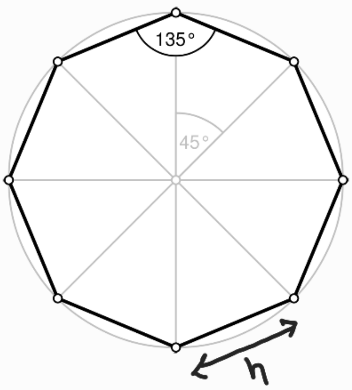
$$4^2h^2\theta^2$$

$$\left[1-\frac{4^2\theta^2}{\pi^2}\right]$$

$x^2 = h^2 - \ldots \pi = h\{1 - \ldots$

$x = h\sqrt{1 - \frac{16\theta^2}{\pi^2}}$

Top View

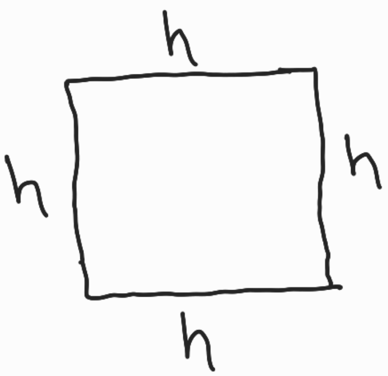


Perimeter of circle $= 2\pi r \approx 8h$

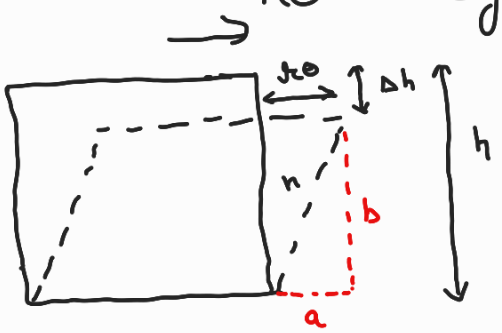
$$r \approx \frac{4h}{\pi}$$

Side View

$\theta = 0$



Rotate by θ



$$a^2 + b^2 = h^2$$

$$\Rightarrow \quad r^2\theta^2 + (h - \Delta h)^2 = h^2$$

$\ldots \quad \Delta h \approx 0$

Considering $\frac{\Delta h}{h}$

$$\Rightarrow \quad r^2\theta^2 + h^2\left(1-\frac{\Delta h}{h}\right)^2 = h^2$$

$$\Rightarrow \quad r^2\theta^2 + h^2\left[1-\frac{2\Delta h}{h}\right] = h^2$$

$$\Rightarrow \quad 2\Delta h\, h = r^2\theta^2$$

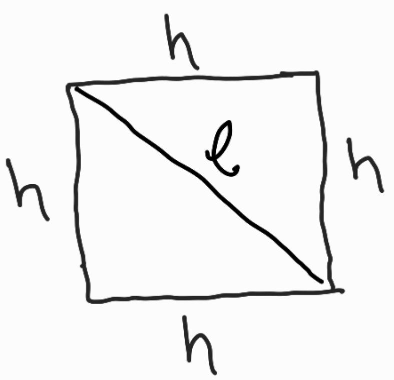
$$\Rightarrow \quad 2\Delta h h = \frac{16h^2}{\pi^2}\theta^2$$

$$\Rightarrow \quad \Delta h = \frac{8h\theta^2}{\pi^2}$$

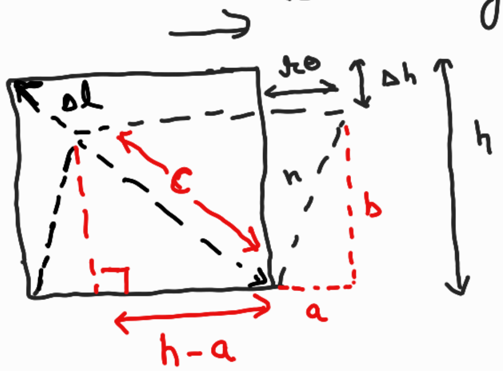
Method 1

Side View

$\theta = 0$



Rotate by θ



$$b^2 + (h-a)^2 = c^2$$

$$\Rightarrow \quad b^2 + (h - r\theta)^2 = (l - \Delta l)^2$$

$$\theta \approx 0 \ , \ \frac{\Delta l}{l} \approx 0 \ , \ \frac{\Delta h}{h} \approx 0$$

$$\Rightarrow (h - \Delta h)^2 + (h - r\theta)^2 = (l - \Delta l)^2$$

$$\Rightarrow \quad h^2 - 2\Delta h h + h^2 - 2r\theta h = l^2 - 2\Delta l \, l$$

$$l^2 = 2h^2$$

$$\Rightarrow \quad \Delta l = (\Delta h + r\theta)\frac{h}{l}$$

$$\Rightarrow \quad \Delta l = \left[\frac{8h\theta^2}{\pi^2} + \frac{4h}{\pi}\theta\right]\frac{1}{\sqrt{2}}$$

Controller

$$\Delta \dot{l} = \left[\frac{16h\,\theta\dot{\theta}}{\pi^2} + \frac{4h\dot{\theta}}{\pi}\right]\frac{1}{\sqrt{2}}$$

$$\Delta\ddot{l} = \left[\frac{16h\dot{\theta}^2}{\pi^2} + \frac{16h\,\dot{\theta}\ddot{\theta}}{\pi^2} + \frac{4h\ddot{\theta}}{\pi} \right] \frac{1}{\sqrt{2}}$$

Now lets assume, Δh desired Contraction

$$\Delta h_{desired} = \frac{8h\,\theta_{desired}^2}{\pi^2}$$

Input is $\Delta\ddot{l} = K_T e$

$$e = \theta_d - \theta$$

$$\dot{e} = -\dot{\theta}$$

$$\ddot{e} = -\ddot{\theta}$$

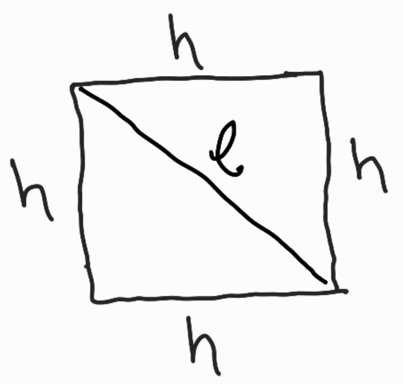
$$K_T e = \left[\frac{16h\dot{e}^2}{\pi^2} + \frac{16h\,\dot{e}\ddot{e}}{\pi^2} - \frac{4h\ddot{e}}{\pi} \right] \frac{1}{\sqrt{2}}$$

$h = 3\text{ cm}$

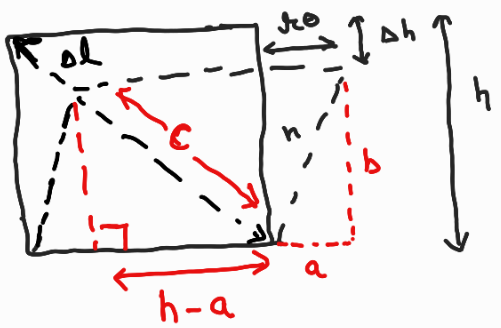
Method 2

Side View

$\theta = 0$



Rotate by θ



$$b^2 + (h-a)^2 = c^2$$

$$\Rightarrow \quad b^2 + (h - r\theta)^2 = (l - \Delta l)^2$$

$$\theta \approx 0 \quad , \quad \frac{\Delta l}{l} \approx 0 \quad , \quad \frac{\Delta h}{h} \approx 0$$

$$\Rightarrow \quad (h - \Delta h)^2 + (h - r\theta)^2 = (l - \Delta l)^2$$

$$\Rightarrow \quad h^2 - 2\Delta h h + h^2 - 2r\theta h = l^2 - 2\Delta l l$$

$$l^2 = 2h^2$$

$$\Rightarrow \quad \Delta l = (\Delta h + r\theta)\frac{h}{l}$$

$$\Rightarrow \quad \Delta l = \left[\frac{8h\theta^2}{\pi^2} + \frac{4h}{\pi}\theta\right]\frac{1}{\sqrt{2}}$$

$$\Rightarrow \quad \Delta l = \frac{2\sqrt{2}h}{\pi}\theta$$

<u>Controller</u>

$$\Delta \dot{l} = \frac{2\sqrt{2}\,h\,\dot{\theta}}{\pi}$$

$$\Delta \ddot{l} = \frac{2\sqrt{2}\,h\,\ddot{\theta}}{\pi}$$

$$\Delta h_{desired} = \frac{8h\,\theta_{desired}^2}{\pi^2}$$

$$\theta_{desired} = \sqrt{\frac{\Delta h_d\,\pi^2}{\ldots}}$$

$$\int \quad 8h$$

Input is $\Delta\ddot{l} = K_T e$

$$e = \theta_d - \theta$$

$$\dot{e} = -\dot{\theta}$$

$$\ddot{e} = -\ddot{\theta}$$

$$\Delta\ddot{l} = 2\sqrt{2}h(-\ddot{e})$$

$$\Delta\ddot{l} = K_p e + K_d \dot{e} + K_I \int e$$

$$\Rightarrow \quad 2\sqrt{2}h\ddot{e} + K_p e + K_d \dot{e} + K_I \int e = 0$$

$$\Rightarrow \quad \ddot{e} + \frac{K_d}{2\sqrt{2}h}\dot{e} + \frac{K_p e}{2\sqrt{2}h} + \frac{K_I \int e}{2\sqrt{2}h} = 0$$