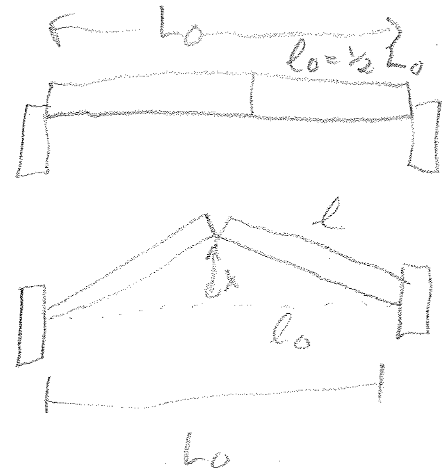
18-21 $L_0 = 3.77m$



$\alpha = 25 \times 10^{-6} / C^\circ$

$\Delta t = 32^\circ C$

How high does it buckle?

$\Delta L = L \alpha \Delta T$ for linear expansion

How long is new "l"?

$l = l_0 + \Delta l = l_0 + l_0 \alpha \Delta T = l_0 (1 + \alpha \Delta T)$

What's "x"?

Pythagoras says: $l^2 = x^2 + l_0^2$

so $x^2 = l^2 - l_0^2 = l_0^2 (1 + \alpha \Delta T)^2 - l_0^2$

$x = l_0 \sqrt{(1 + \alpha \Delta T)^2 - 1}$

$= \frac{3.77m}{2} \sqrt{(1 + (25 \times 10^{-6} / {}^\circ C)(32^\circ C))^2 - 1}$

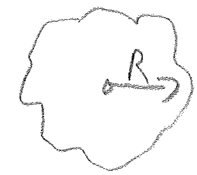
$= 1.885 \sqrt{(1 + 800 \times 10^{-6})^2 - 1}$

$= 7.5 \times 10^{-2} m =$ **7.5 cm**

8-56 Bees heat up from $35°C \to 47°C$ for 20 min to kill wasp.

$R = 2.0\ cm$

Bee's emissivity $\varepsilon = 0.80$



Ball-o-bees

How much extra energy do the bees have to put out to do this?

P radiated by heat is $P = \sigma \varepsilon A T^4$ (T in kelvin!)

$\Delta P = P_{47°} - P_{35°} = \sigma \varepsilon A T_{47}^4 - \sigma \varepsilon A T_{35}^4$

$\Delta P = \sigma \varepsilon A \left(T_{47}^4 - T_{35}^4\right)$

$T_{35} = (273 + 35)\ K = 308\ K$ $\quad T_{47} = (273 + 47)\ K = 320\ K$

$2 \times 10^{-2}\ m$

$\sigma = 5.67 \times 10^{-8}\ W/m^2$ $\quad \varepsilon = 0.80$ $\quad A = 4\pi R^2 = 5.03 \times 10^{-3}\ m^2$

so $\Delta P = 0.34\ W$

How much energy per bee?

$P = \text{Energy}/\text{time}$ so $\text{Energy} = P \cdot t$,

so $\dfrac{\text{Energy}}{\text{bee}} = \dfrac{0.34\ W \cdot 20\ min \cdot 60\ s/min}{500\ bees} = \boxed{0.81\ J}$