

Steps of Solving an Engineering Problem



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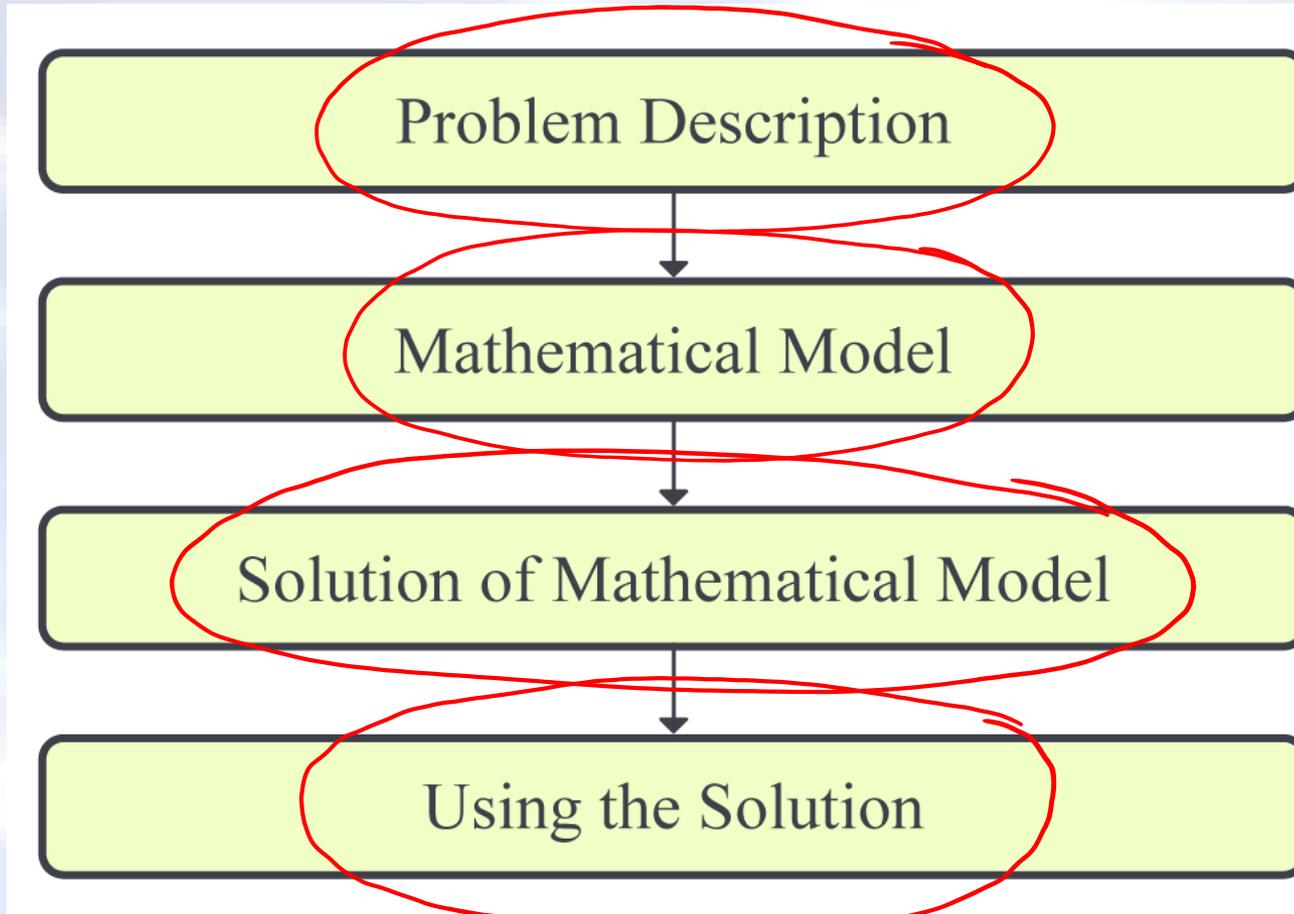


For more resources and playlist on this topic

- Go to <http://nm.MathForCollege.com>
- Click on Introduction to Numerical Methods



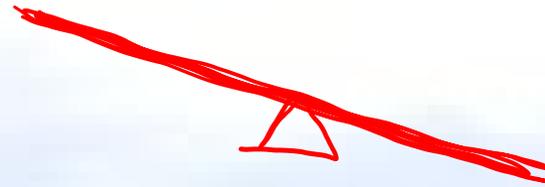
How do we solve an engineering problem?



PROBLEM DESCRIPTION



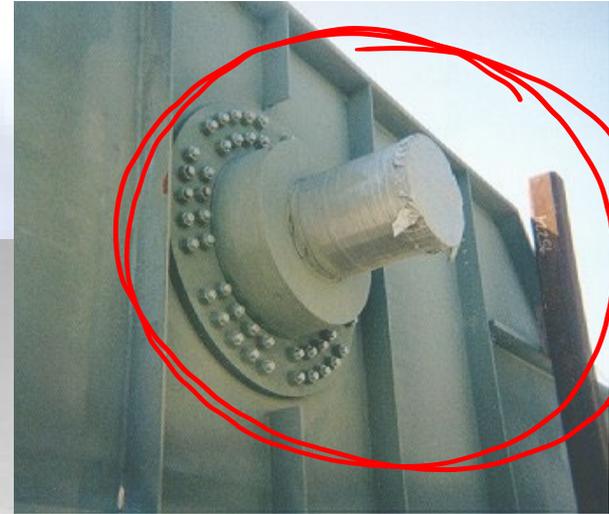
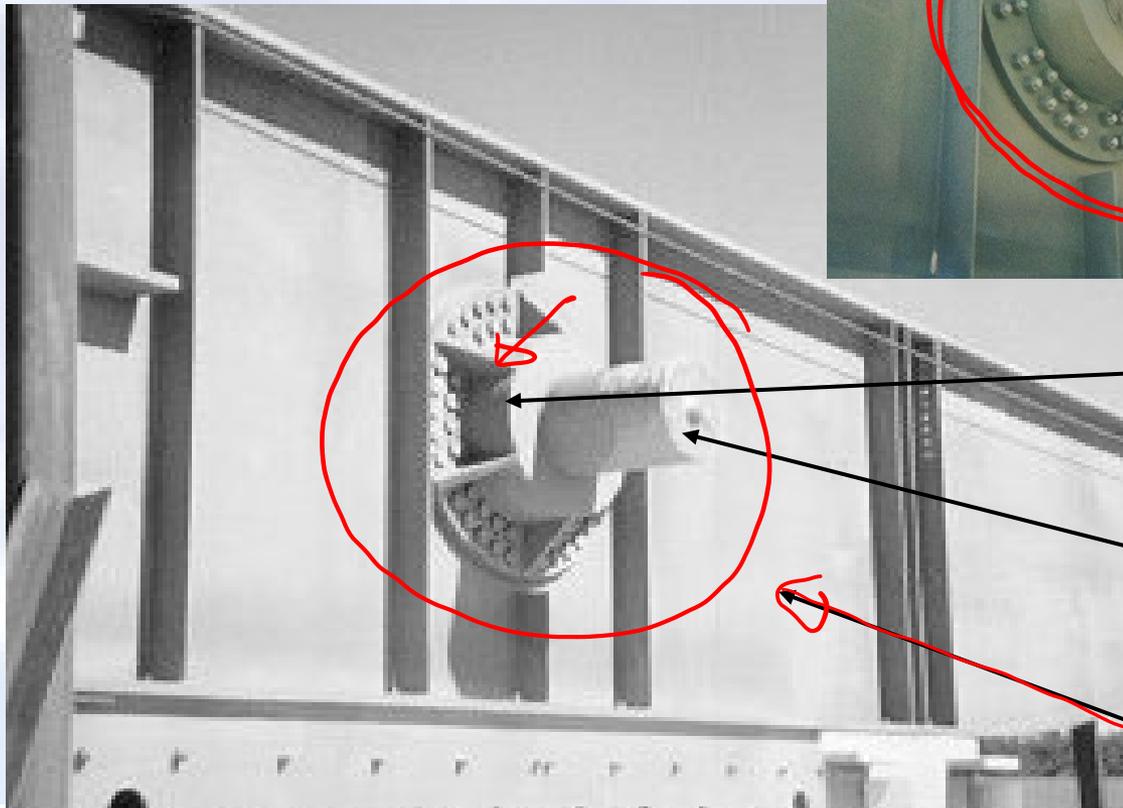
Example of Solving an Engineering Problem



Bascule Bridge THG



Bascule Bridge THG



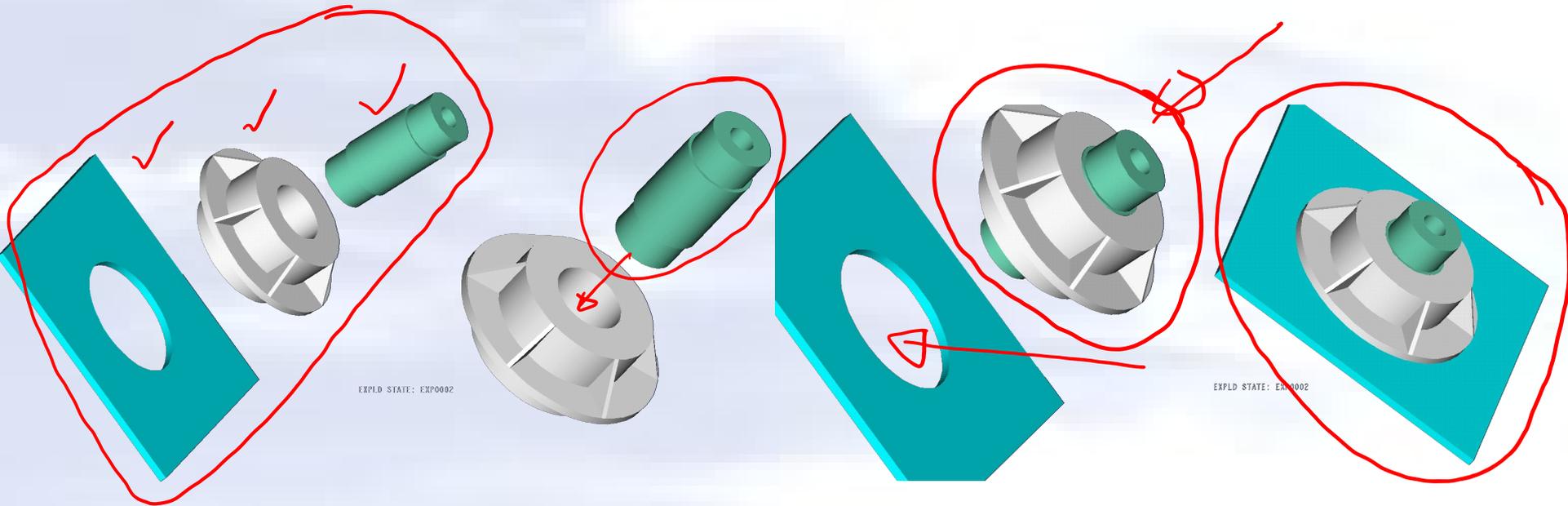
Hub

Trunnion

Girder



Trunnion-Hub-Girder Assembly Procedure



Step1.

Trunnion immersed in dry-ice/alcohol

Step2.

Trunnion shrink fit and warm up

Step3.

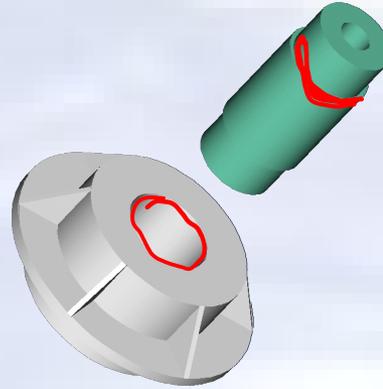
Trunnion-hub immersed in dry-ice/alcohol

Step4.

Trunnion-hub shrink fit and warm-up



Problem

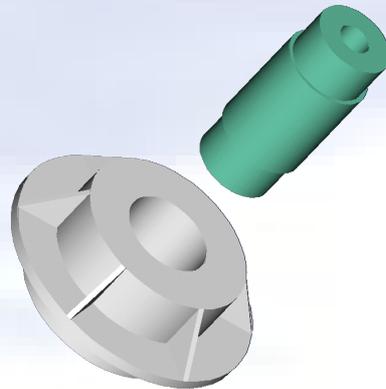
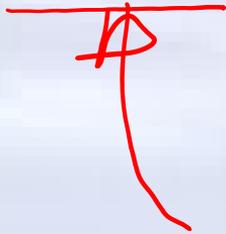


After cooling the trunnion, the trunnion got stuck in hub



Why did it get stuck?

Magnitude of contraction needed in the trunnion
was 0.015" or more. Did it contract enough?



$$|\Delta D| \geq \underline{\underline{0.015''}}$$



MATHEMATICAL MODELING



Consultant Calculations

$$\Delta D = D \alpha \Delta T$$

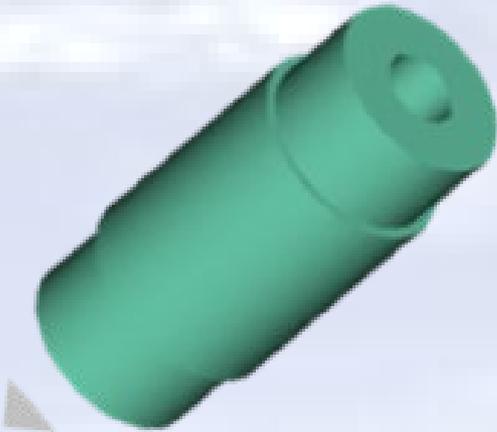
$$D = 12.363''$$

$$\alpha = 6.47 \times 10^{-6} \text{ in/in/}^\circ\text{F}$$

$$\begin{aligned} \Delta T &= T_a - T_c \\ &= -108 - 80 \\ &= -188^\circ\text{F} \end{aligned}$$

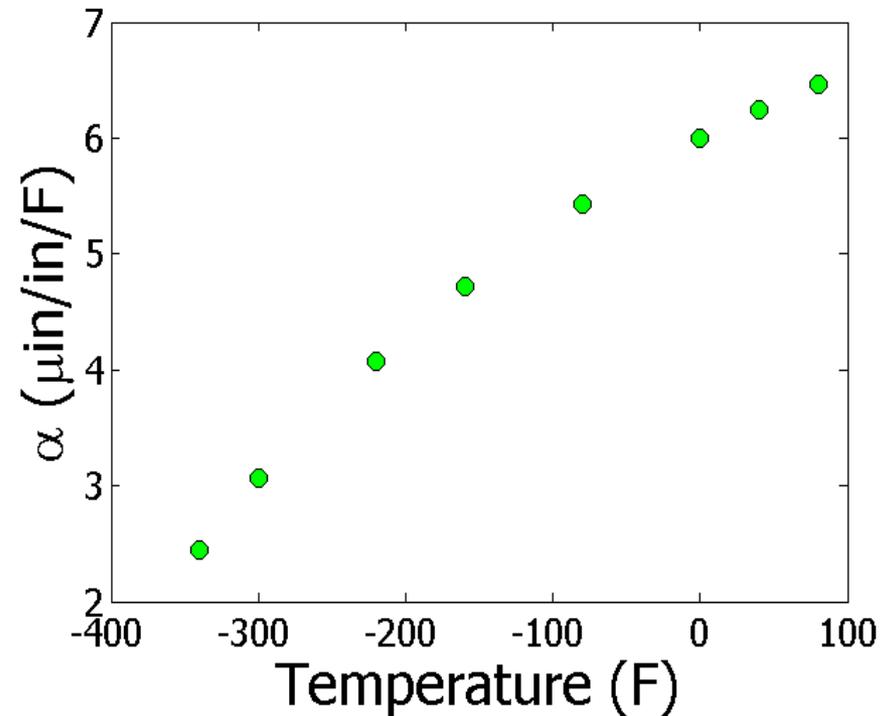
$$\begin{aligned} \Delta D &= (12.363)(6.47 \times 10^{-6})(-188) \\ &= -0.01504'' \end{aligned}$$

$$|\Delta D| = 0.01504'' \geq 0.015''$$



Is the $\Delta D = D\alpha\Delta T$ formula correct?

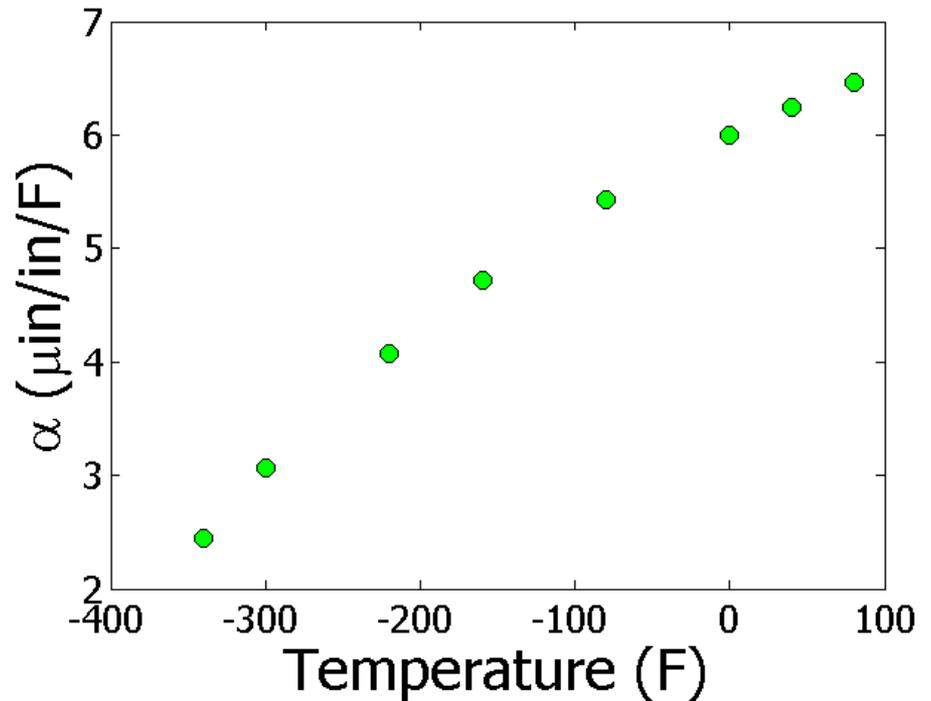
$T(^{\circ}\text{F})$	α ($\mu\text{in}/\text{in}/^{\circ}\text{F}$)
-340	2.45 ✓
-300	3.07 ✓
-220	4.08 ✓
-160	4.72 ✓
-80	5.43 ✓
0	6.00 ✓
40	6.24 ✓
80	6.47 ✓



The correct model would account for varying thermal expansion coefficient

$$\Delta D = D \int_{T_a}^{T_c} \alpha(T) dT$$

~~$\Delta D = D \alpha \Delta T$~~



SOLUTION OF MATHEMATICAL MODEL



Can you roughly estimate the contraction?

$|\Delta D| < 0.015''$

$$\Delta D = D \int_{T_a}^{T_c} \alpha(T) dT$$

$$T_a = 80^\circ\text{F}$$

$$T_c = -108^\circ\text{F}$$

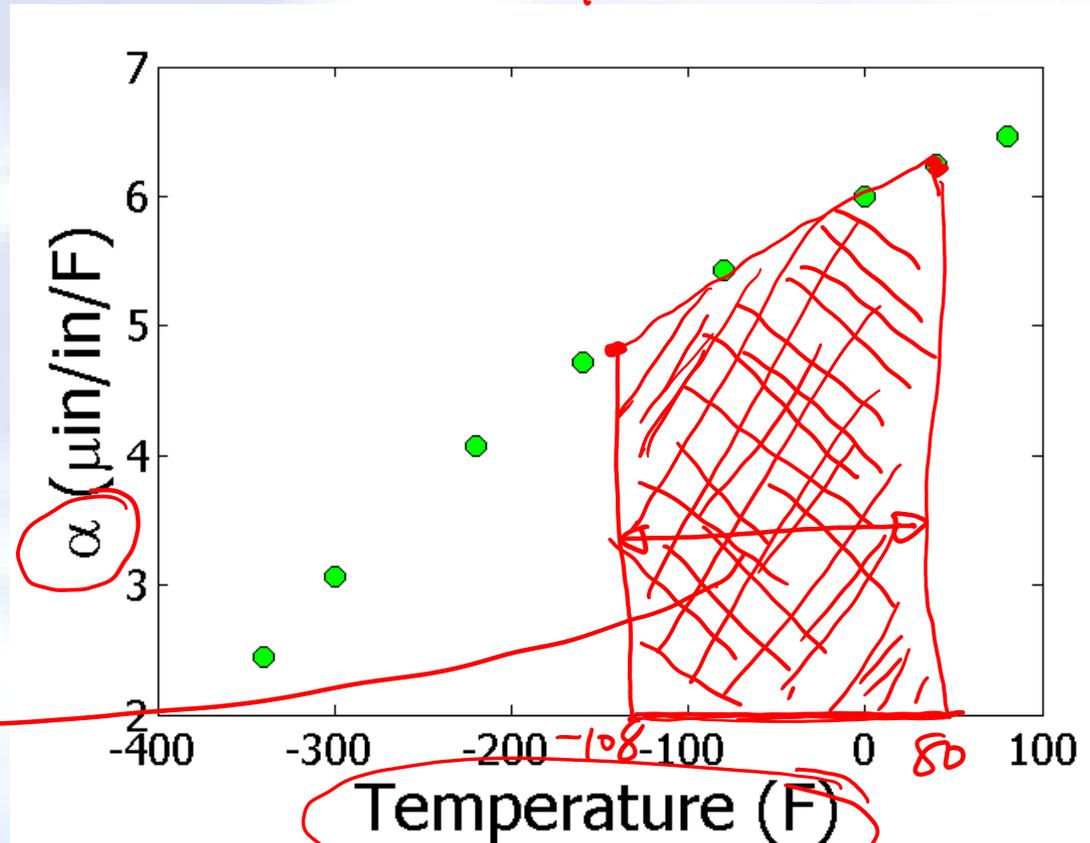
$$D = 12.363''$$

$$\left(\frac{5 \times 10^{-6} + 6.0 \times 10^{-6}}{2} \right) \times (-188)$$

$$= \sim 1081 \times 10^{-6}$$

$$\Delta D = 12.363 \times (-1081 \times 10^{-6})$$

$$= \underline{\underline{-0.013364''}}$$



Can you estimate the contraction more accurately?

$$\alpha = -1.2278 \times 10^{-5} T^2 + 6.1946 \times 10^{-3} T + 6.0150$$

$$\Delta D = D \int_{T_a}^{T_c} \alpha(T) dT$$

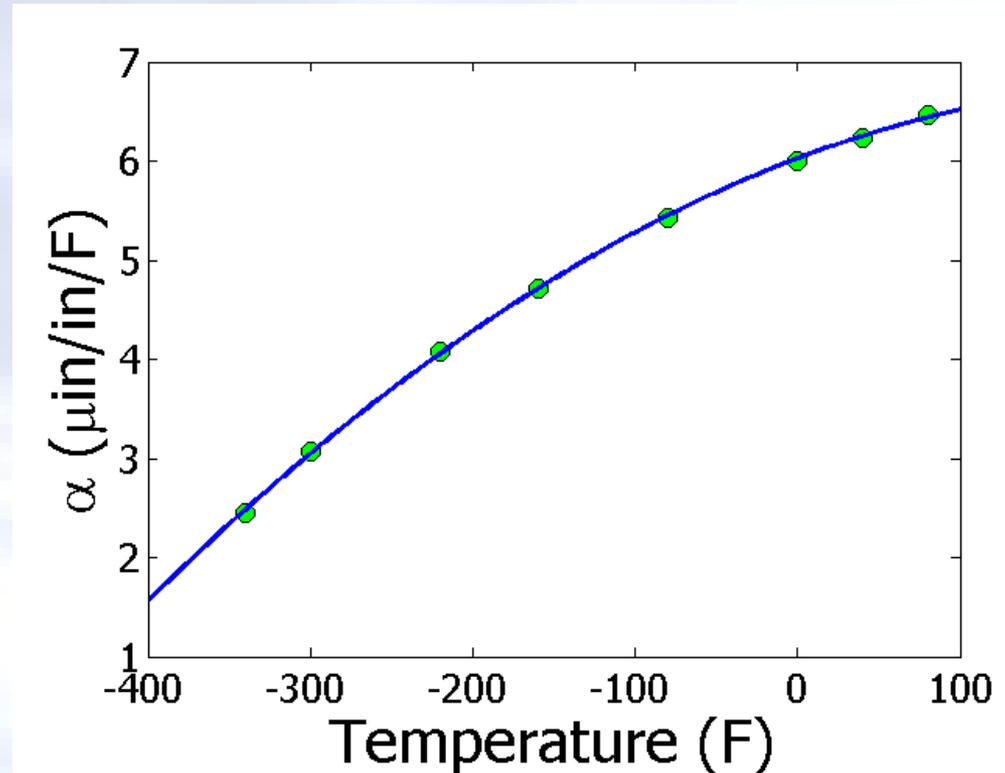
$$T_a = 80^\circ\text{F}$$

$$T_c = -108^\circ\text{F}$$

$$D = 12.363''$$

$$\Delta D = -0.0137''$$

$$|\Delta D| < 0.015''$$



USING THE SOLUTION



So, what is the solution to the problem?

$$\alpha = -1.2278 \times 10^{-5} T^2 + 6.1946 \times 10^{-3} T + 6.0150$$

$$\Delta D = D \int_{T_a}^{T_c} \alpha(T) dT$$

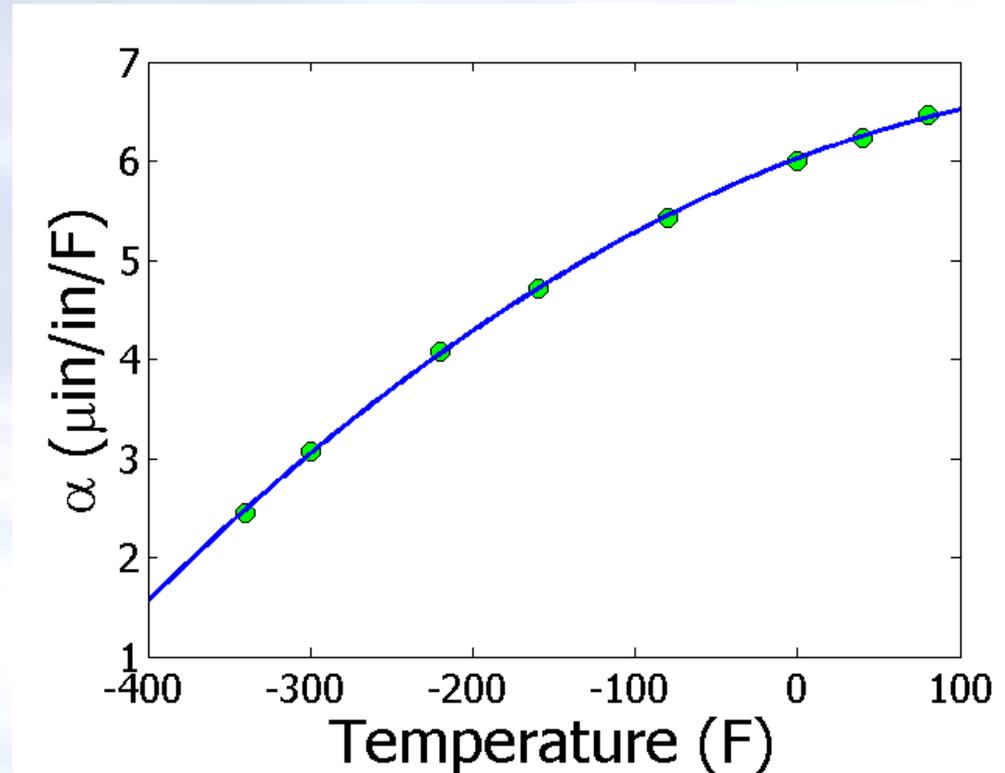
$$T_a = 80^\circ\text{F}$$

$$T_c = -321^\circ\text{F}$$

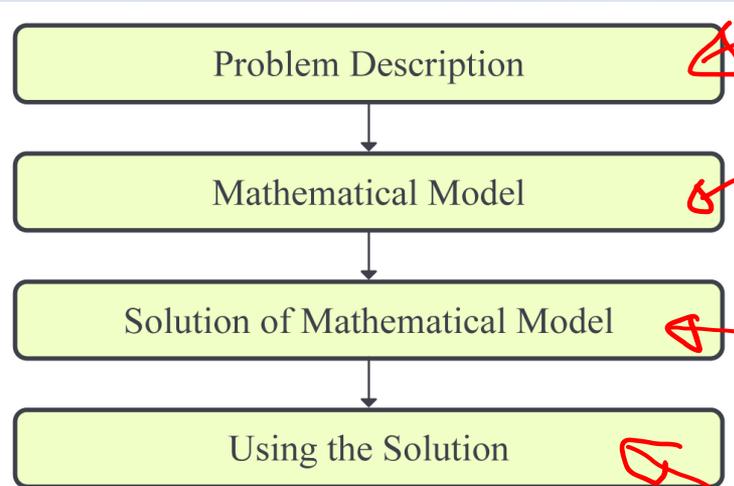
$$D = 12.363''$$

$$\Delta D = -0.0244''$$

$$|\Delta D| > 0.015''$$



Revisiting steps to solve an engineering problem



Truncation got stuck

$$\Delta D = D \frac{\Delta T}{T_c}$$

$$\Delta D = D \frac{\int_{T_c} \alpha(T) dT}{T_c}$$

1) Rough - Trapezoidal Rule

2) Accurate - Represents to a 2nd order polynomial + integrate:

Let's put it in liquid N₂



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