

# Introduction to Scientific Computing

Major: All Engineering Majors

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<http://numericalmethods.eng.usf.edu>

Transforming Numerical Methods Education for STEM Undergraduates

# Introduction



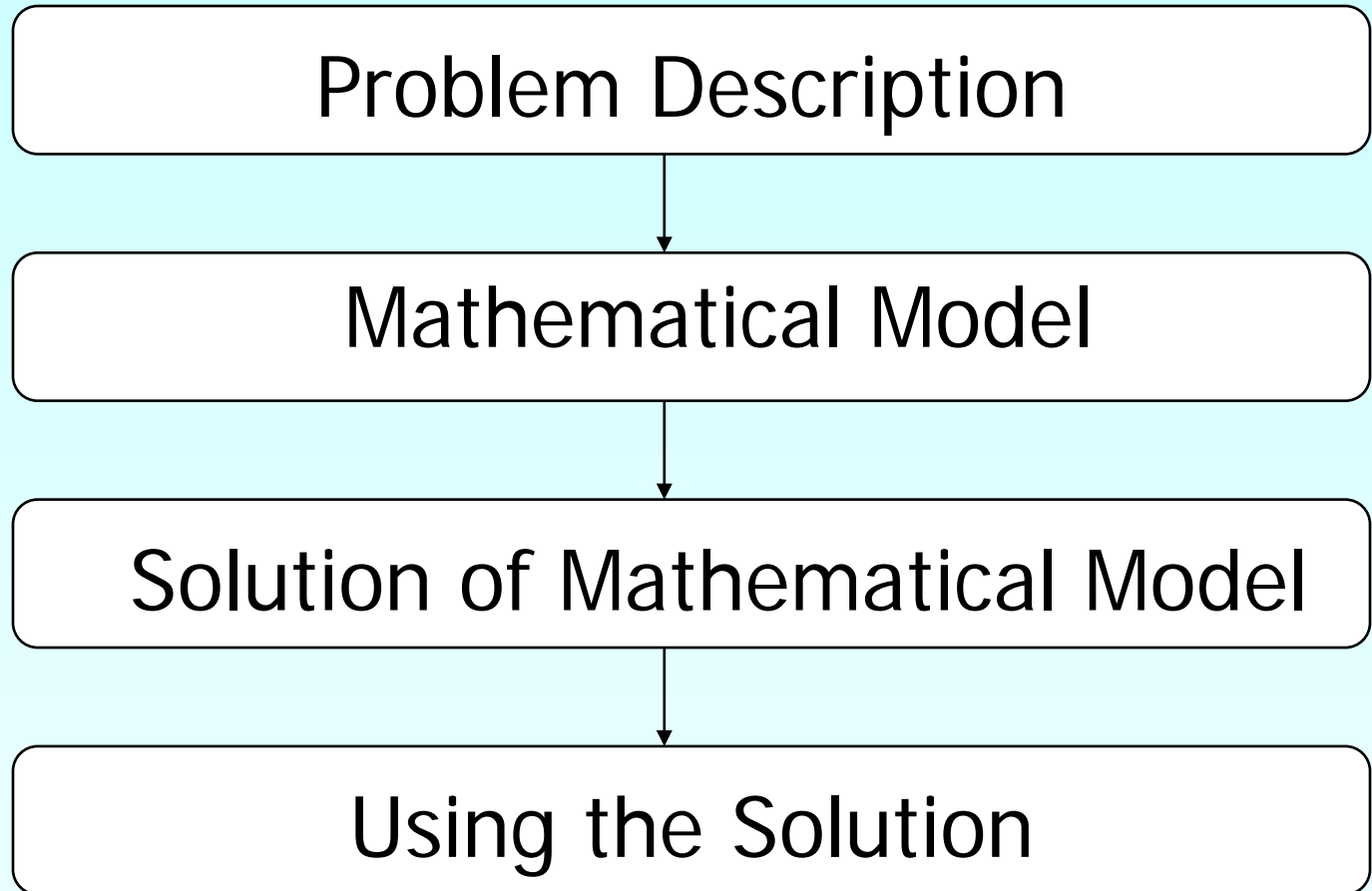
# My advice

- *If you don't let a teacher know at what level you are by asking a question, or revealing your ignorance you will not learn or grow.*
- *You can't pretend for long, for you will eventually be found out. Admission of ignorance is often the first step in our education.*
  - *Steven Covey—Seven Habits of Highly Effective People*

# Steps in Solving an Engineering Problem

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# How do we solve an engineering problem?



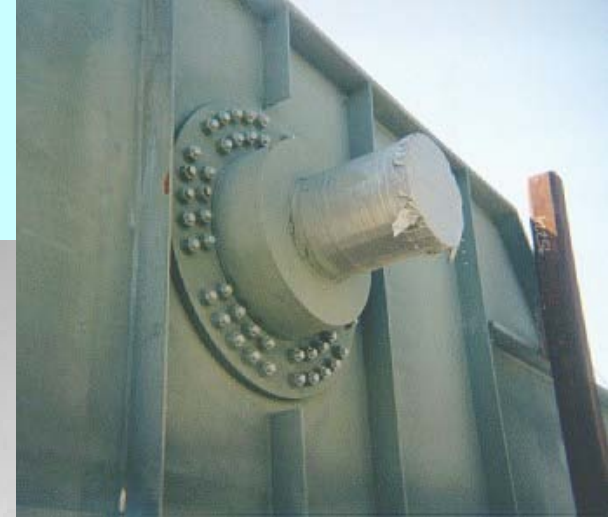
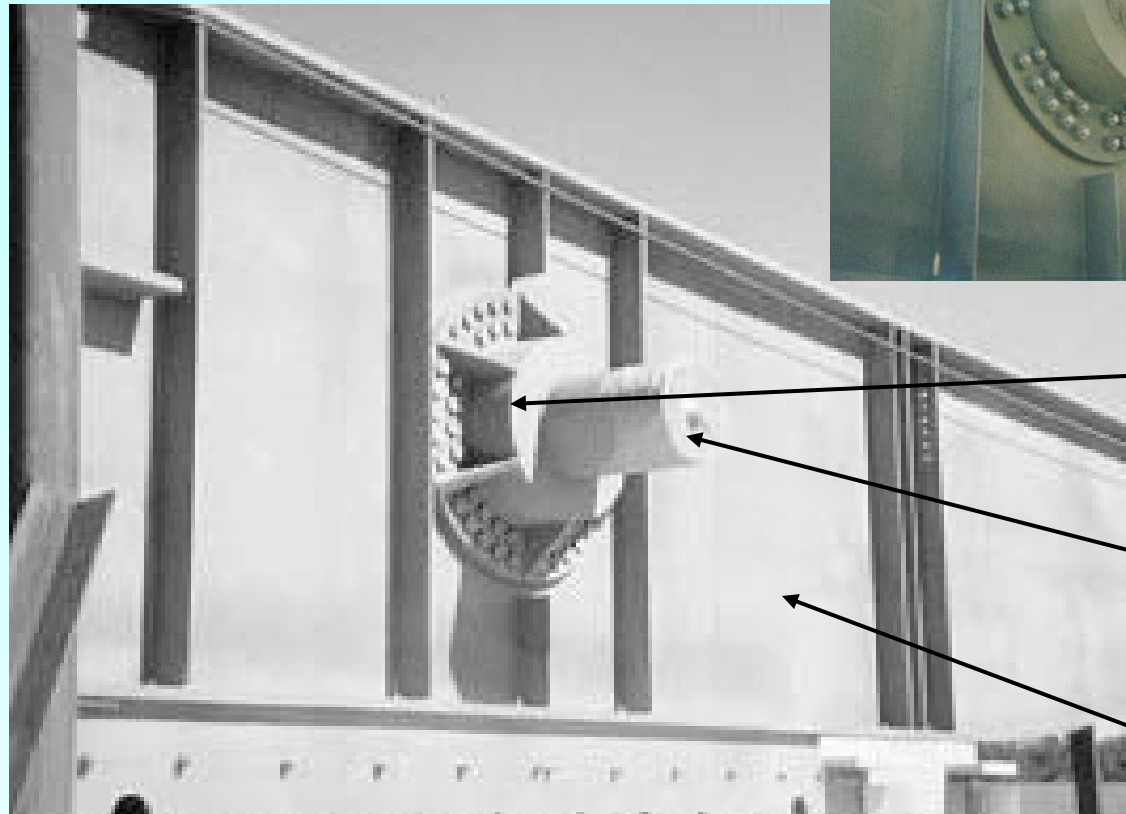
# Example of Solving an Engineering Problem



# Bascule Bridge THG



# Bascule Bridge THG



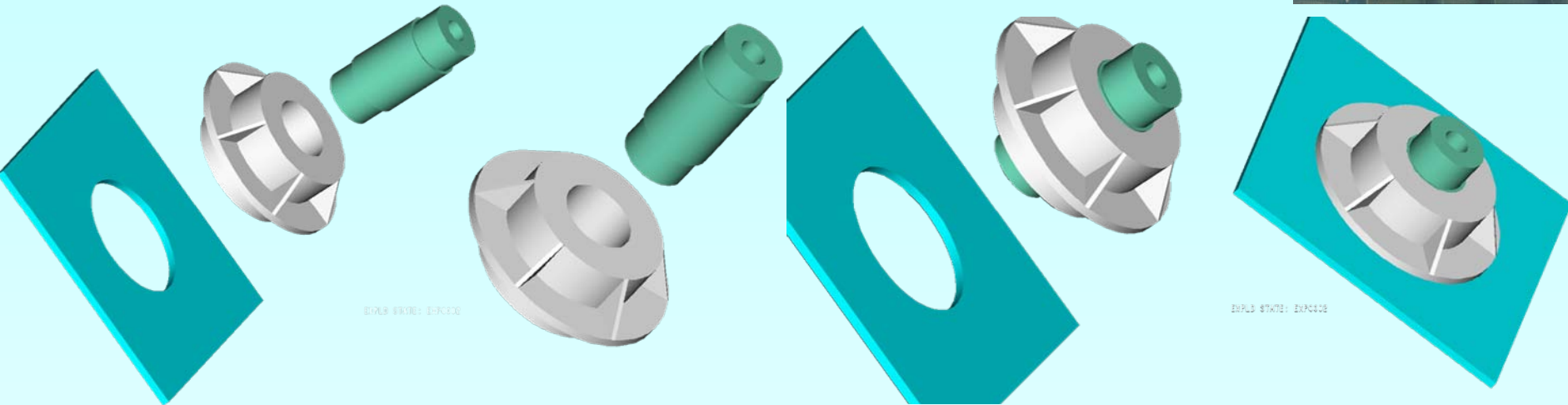
**Hub**

**Trunnion**

**Girder**



# Trunnion-Hub-Girder Assembly Procedure



**Step1.**

Trunnion immersed in dry-ice/alcohol

**Step2.**

Trunnion warm-up in hub

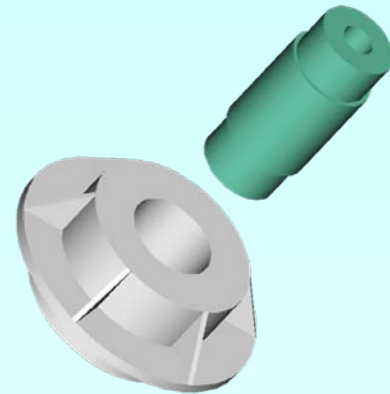
**Step3.**

Trunnion-Hub immersed in  
dry-ice/alcohol

**Step4.**

Trunnion-Hub warm-up into girder

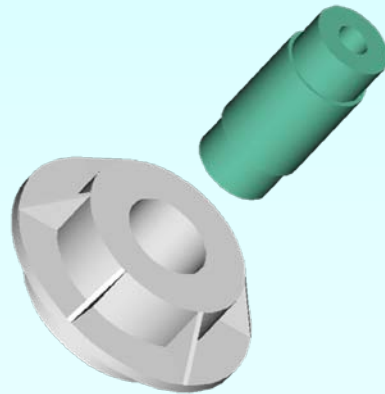
# Problem



After Cooling, 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?



# Video of Assembly Process

Trunnion-Hub-Girder  
Assembly of Bascule Bridges

University of South Florida  
Tampa

Glen Besterfield (PI)  
Autar Kaw (Co-PI)  
Roger Crane (Co-PI)  
Michael Denninger (Grad Student)  
Badri Ratnam (Grad Student)  
Sanjeev Nichani (Grad Student)

Unplugged Version

Trunnion-Hub-Girder  
Assembly of Bascule Bridges

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VH1 Version

# Consultant calculations

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

$$D = 12.363''$$

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

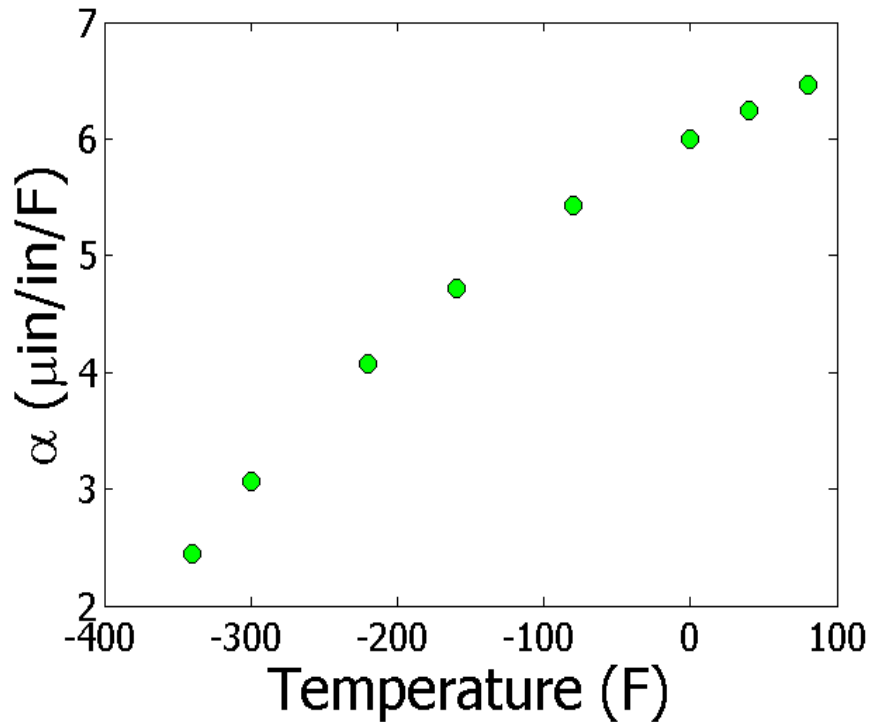
$$\Delta T = -108 - 80 = -188^\circ F$$

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



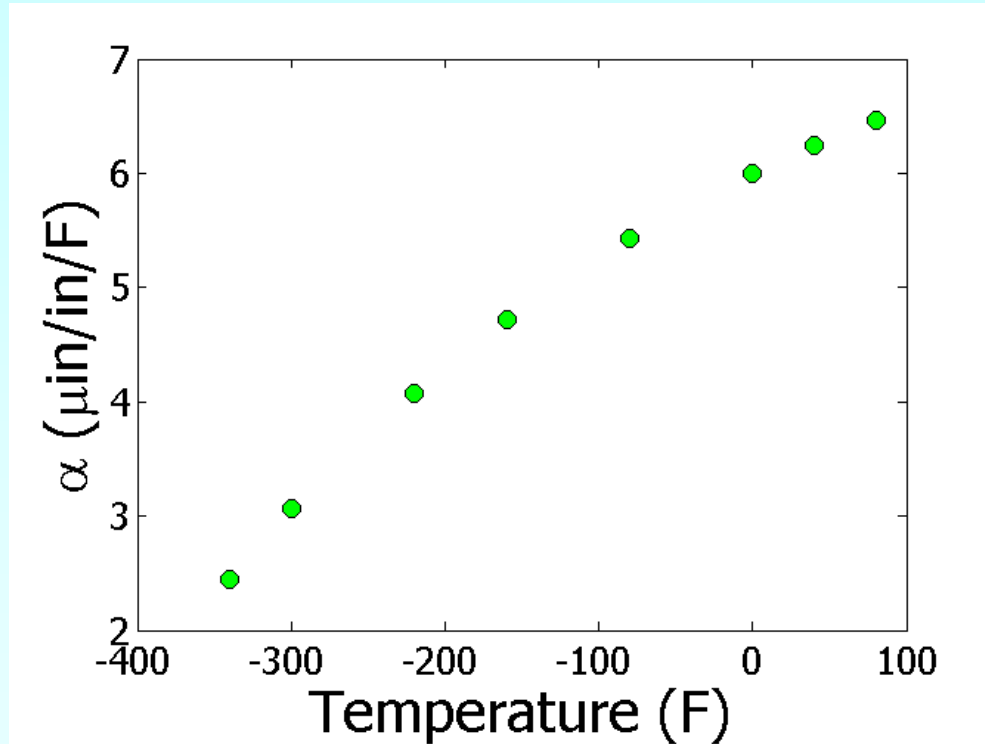
# Is the formula used correct?

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



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

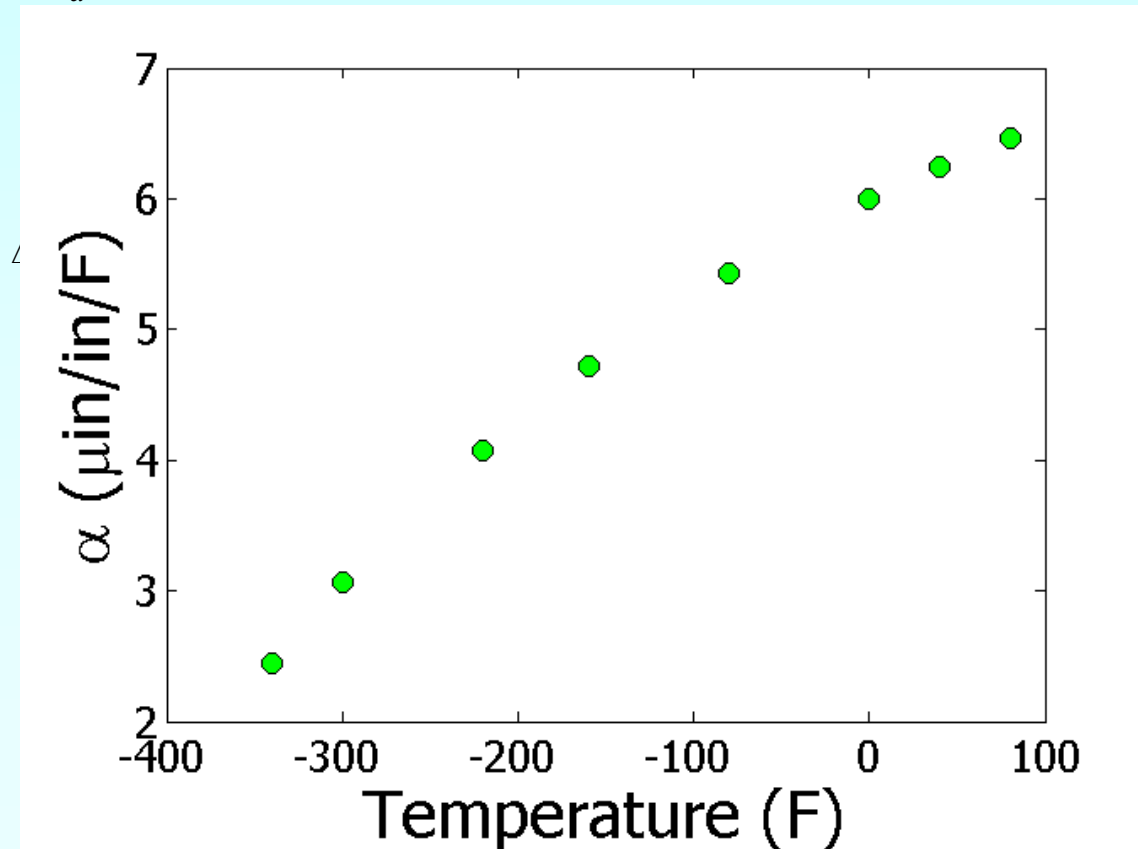
# The Correct Model Would Account for Varying Thermal Expansion Coefficient



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

# Can You Roughly Estimate the Contraction?

$$\Delta D = D \int_{T_a}^{T_c} \alpha(T) dT \quad T_a = 80^\circ\text{F}; T_c = -108^\circ\text{F}; D = 12.363''$$





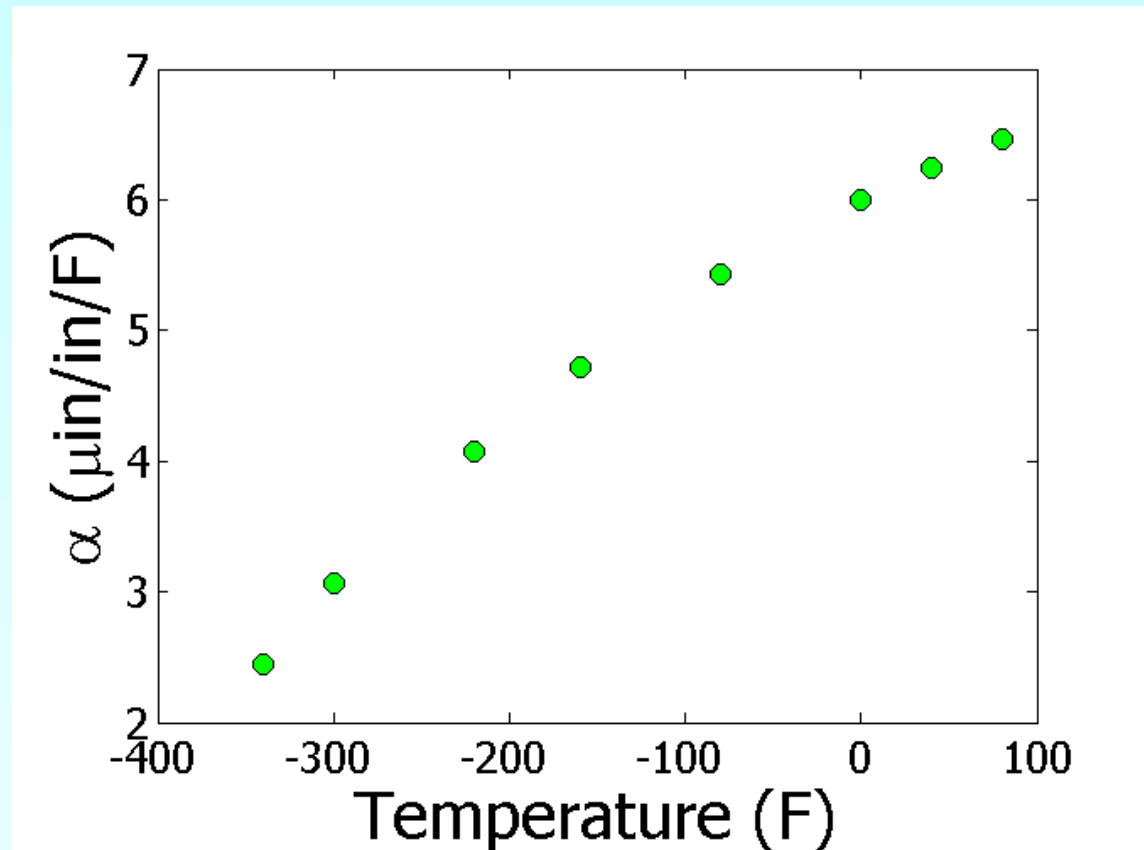
# Can You Find a Better Estimate for the Contraction?

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

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

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

$$D = 12.363''$$



# Estimating Contraction Accurately

Change in diameter ( $\Delta D$ ) by cooling it in dry ice/alcohol is given by

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

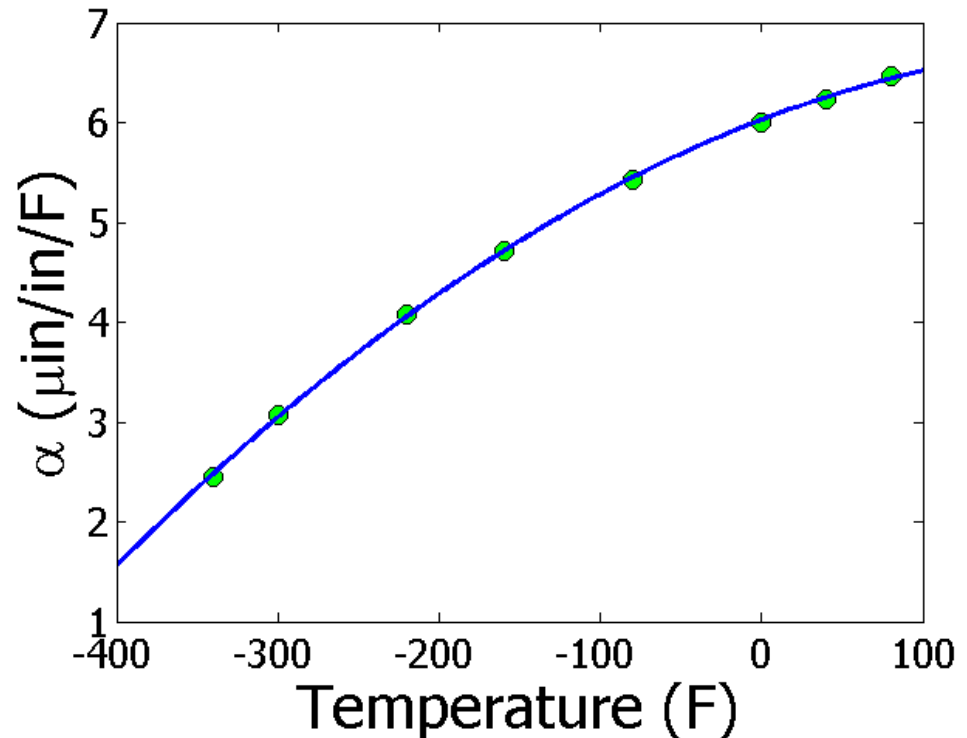
$$T_a = 80^\circ\text{F}$$

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

$$D = 12.363''$$

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

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



# So what is the solution to the problem?

One solution is to immerse the trunnion in liquid nitrogen which has a boiling point of  $-321^{\circ}\text{F}$  as opposed to the dry-ice/alcohol temperature of  $-108^{\circ}\text{F}$ .

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

# Revisiting steps to solve a problem

- 1) Problem Statement: Trunnion got stuck in the hub.
- 2) Modeling: Developed a new model

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

- 3) Solution: 1) Used trapezoidal rule OR b) Used regression and integration.
- 4) Implementation: Cool the trunnion in liquid nitrogen.

**THE END**

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# Introduction to Numerical Methods

## Mathematical Procedures

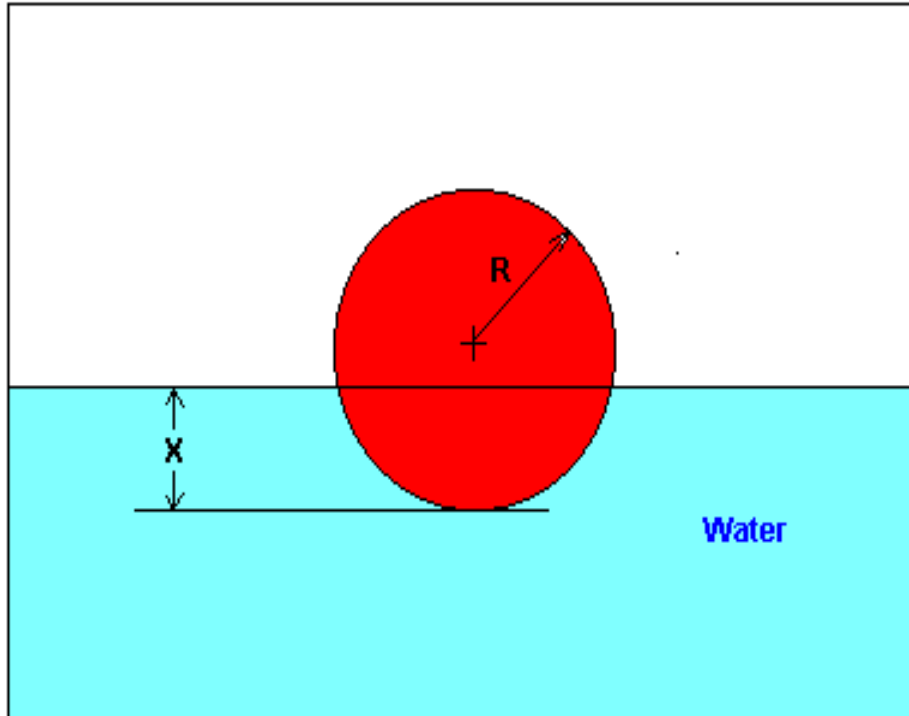
<http://numericalmethods.eng.usf.edu>

# Mathematical Procedures

- Nonlinear Equations
- Differentiation
- Simultaneous Linear Equations
- Curve Fitting
  - Interpolation
  - Regression
- Integration
- Ordinary Differential Equations
- Other Advanced Mathematical Procedures:
  - Partial Differential Equations
  - Optimization
  - Fast Fourier Transforms

# Nonlinear Equations

How much of the floating ball is under water?



Diameter=0.11m

Specific Gravity=0.6

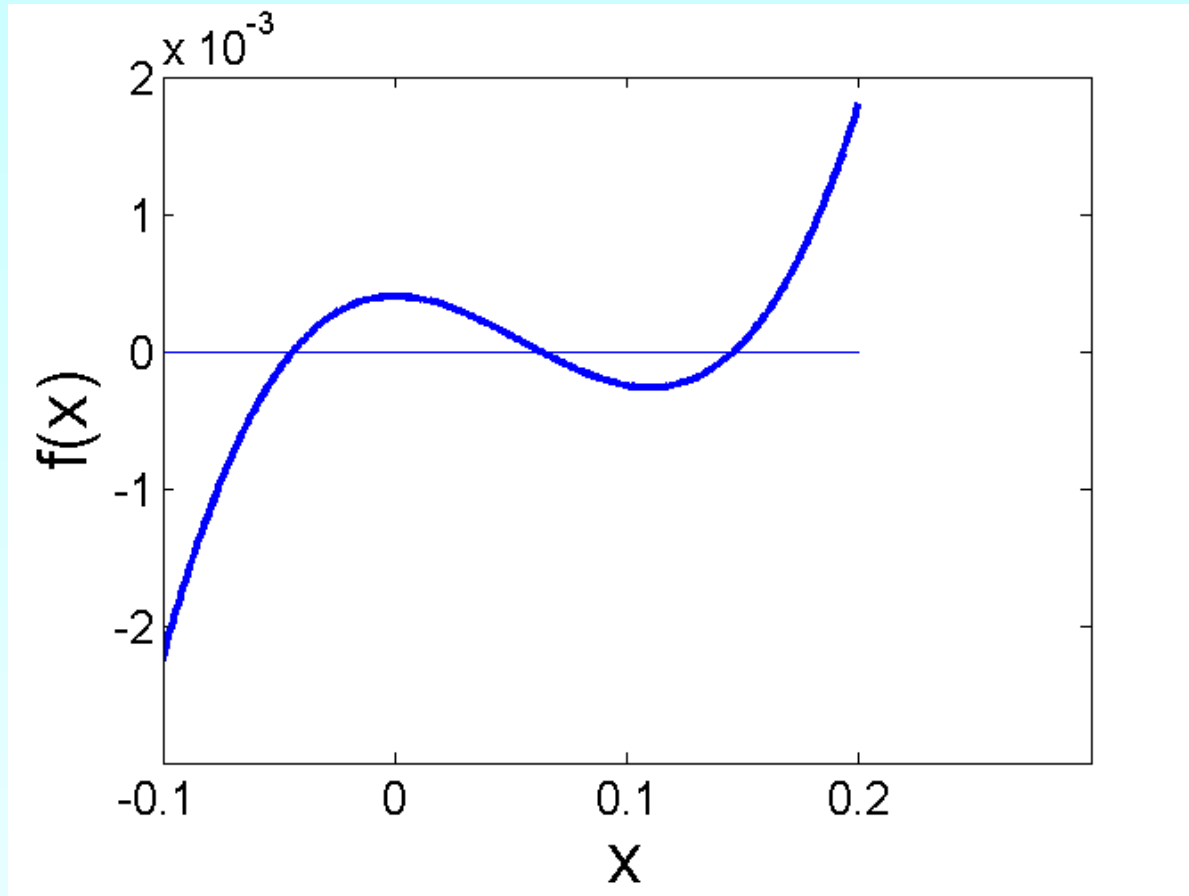
$$x^3 - 0.165x^2 + 3.993 \times 10^{-4} = 0$$

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# Nonlinear Equations

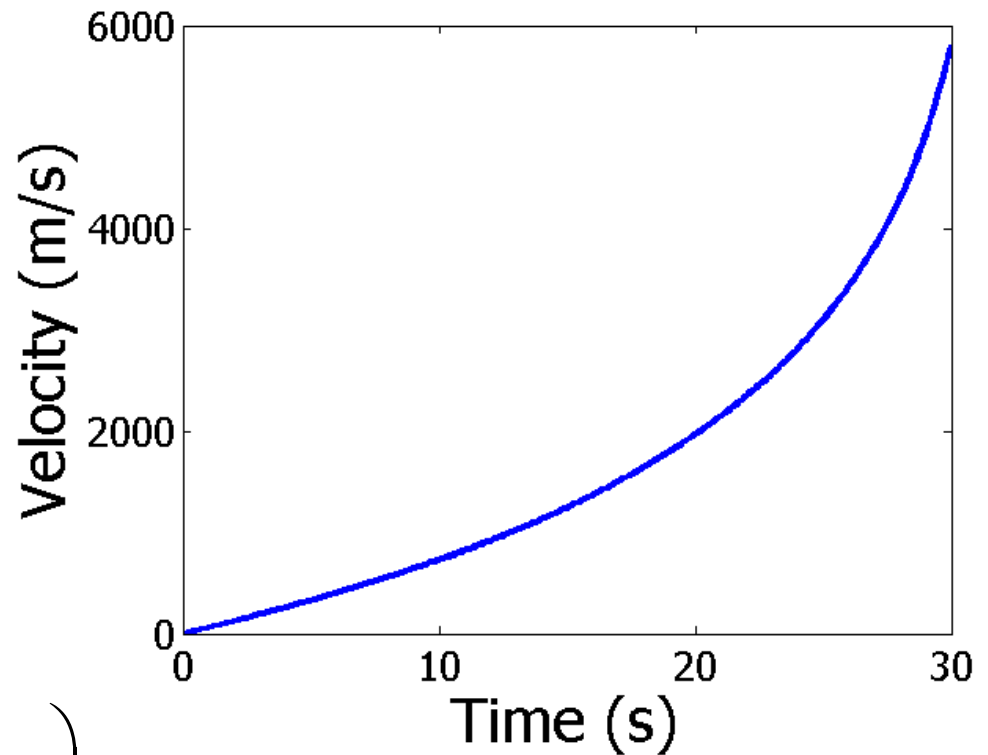
How much of the floating ball is under the water?



$$f(x) = x^3 - 0.165x^2 + 3.993 \times 10^{-4} = 0$$

# Differentiation

What is the acceleration  
at  $t=7$  seconds?



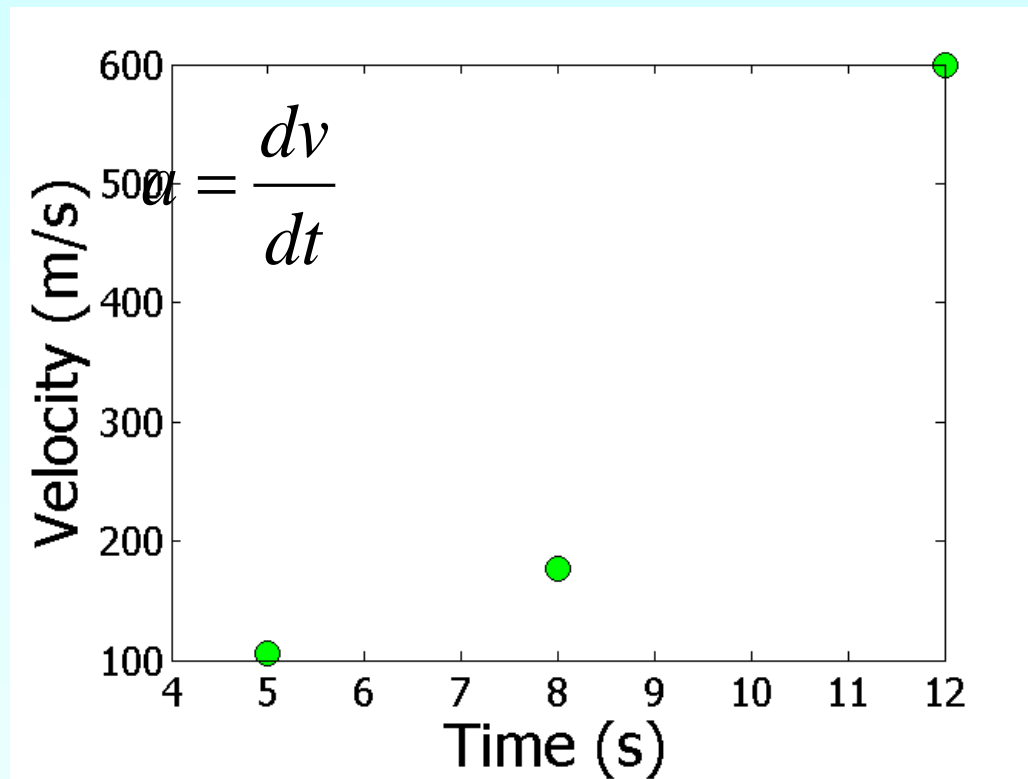
$$v(t) = 2200 \ln\left(\frac{16 \times 10^4}{16 \times 10^4 - 5000t}\right) - 9.8t$$

$$a = \frac{dv}{dt}$$

# Differentiation

What is the acceleration at  $t=7$  seconds?

Time (s)	5	8	12
Vel (m/s)	106	177	600



# Simultaneous Linear Equations

Find the velocity profile, given

Time (s)	5	8	12
Vel (m/s)	106	177	600



$$v(t) = at^2 + bt + c, 5 \leq t \leq 12$$

Three simultaneous linear equations

$$25a + 5b + c = 106$$

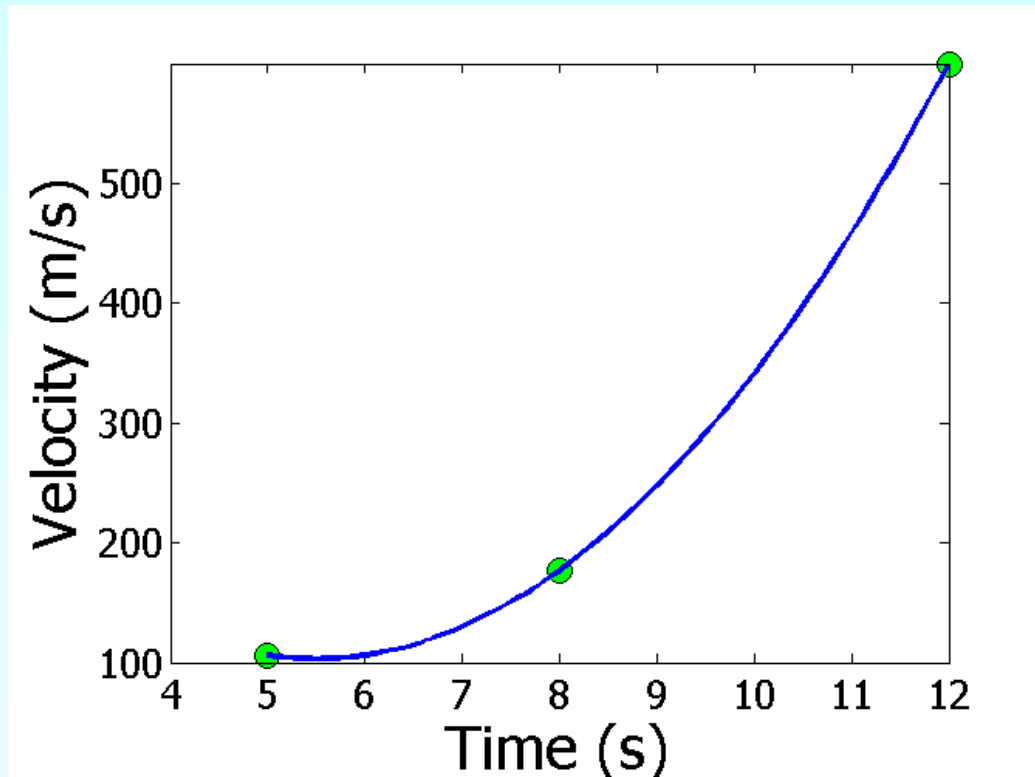
$$64a + 8b + c = 177$$

$$144a + 12b + c = 600$$

# Interpolation

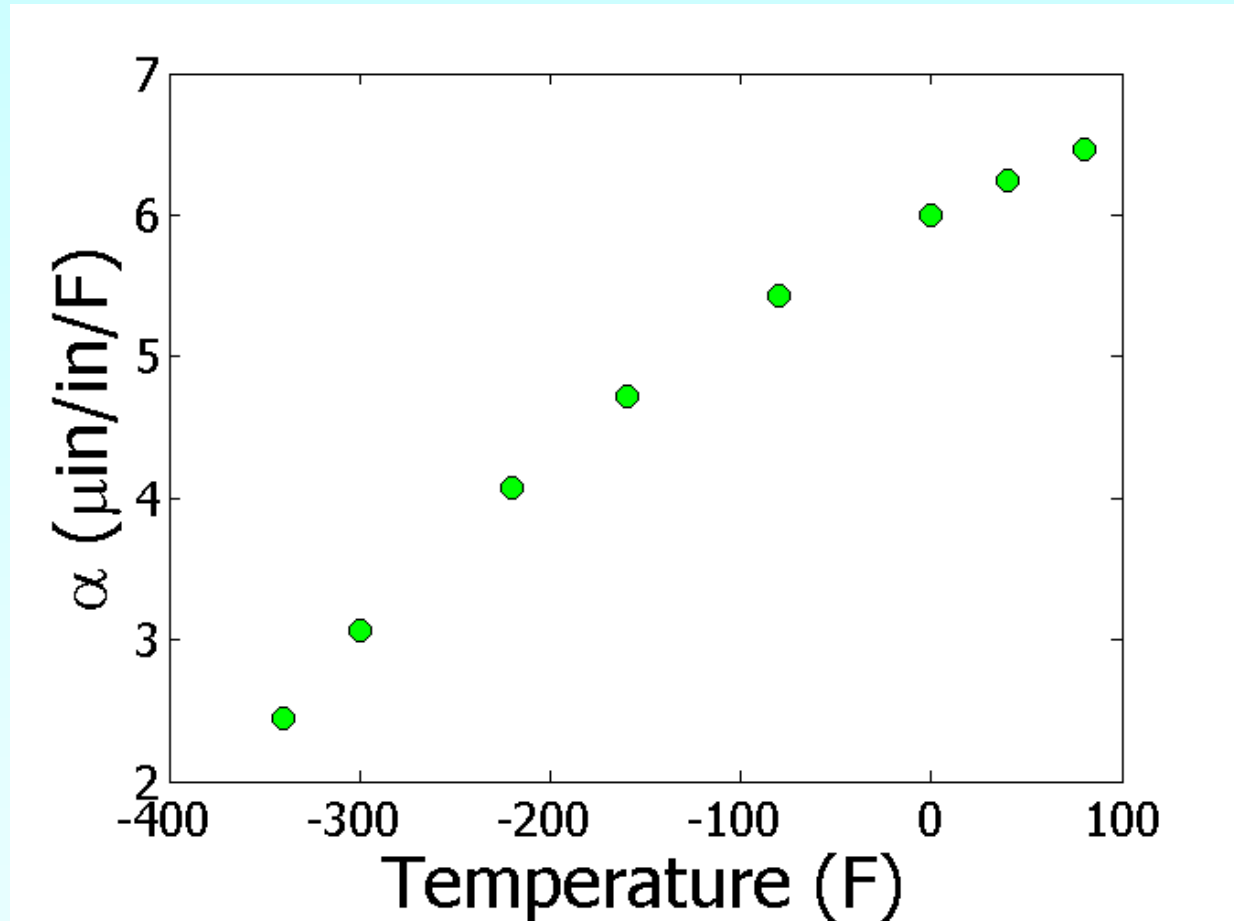
What is the velocity of the rocket at  $t=7$  seconds?

Time (s)	5	8	12
Vel (m/s)	106	177	600

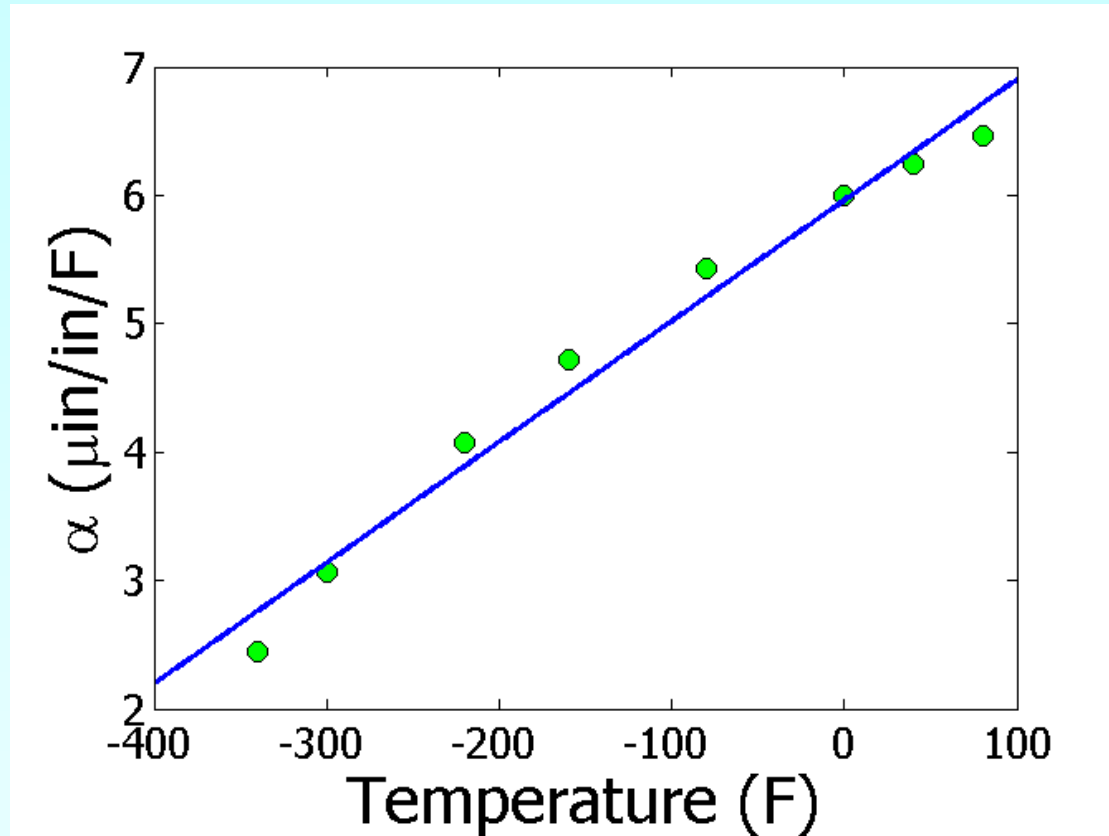


# Regression

Thermal expansion coefficient data for cast steel



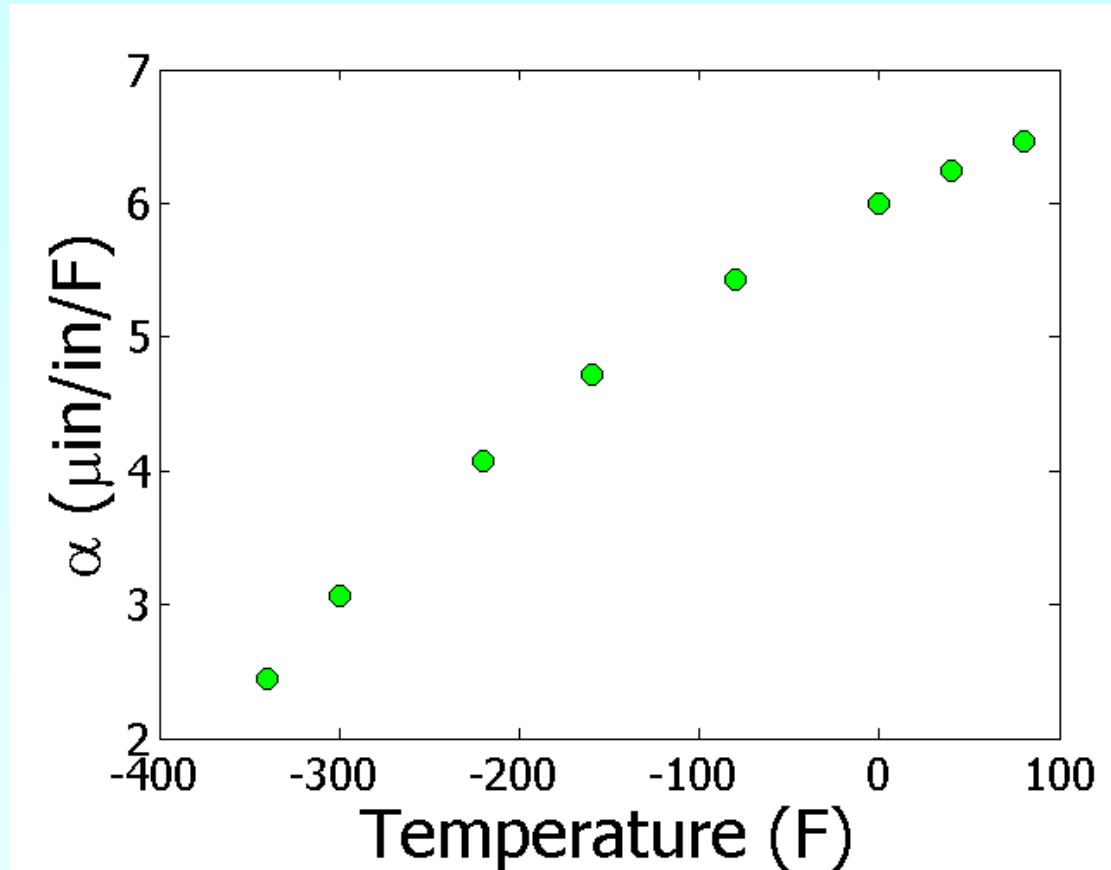
# Regression (cont)



# Integration

Finding the diametric contraction in a steel shaft when dipped in liquid nitrogen.

$$\Delta D = D \int_{T_{room}}^{T_{fluid}} \alpha dT$$





# Ordinary Differential Equations

How long does it take a trunnion to cool down?



$$mc \frac{d\theta}{dt} = -hA(\theta - \theta_a), \theta(0) = \theta_{room}$$

# Additional Resources

For all resources on this topic such as digital audiovisual lectures, primers, textbook chapters, multiple-choice tests, worksheets in MATLAB, MATHEMATICA, MathCad and MAPLE, blogs, related physical problems, please visit

[http://numericalmethods.eng.usf.edu/topics/introduction\\_numerical.html](http://numericalmethods.eng.usf.edu/topics/introduction_numerical.html)

**THE END**

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