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?

Problem Description

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Mathematical Model

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Solution of Mathematical Model

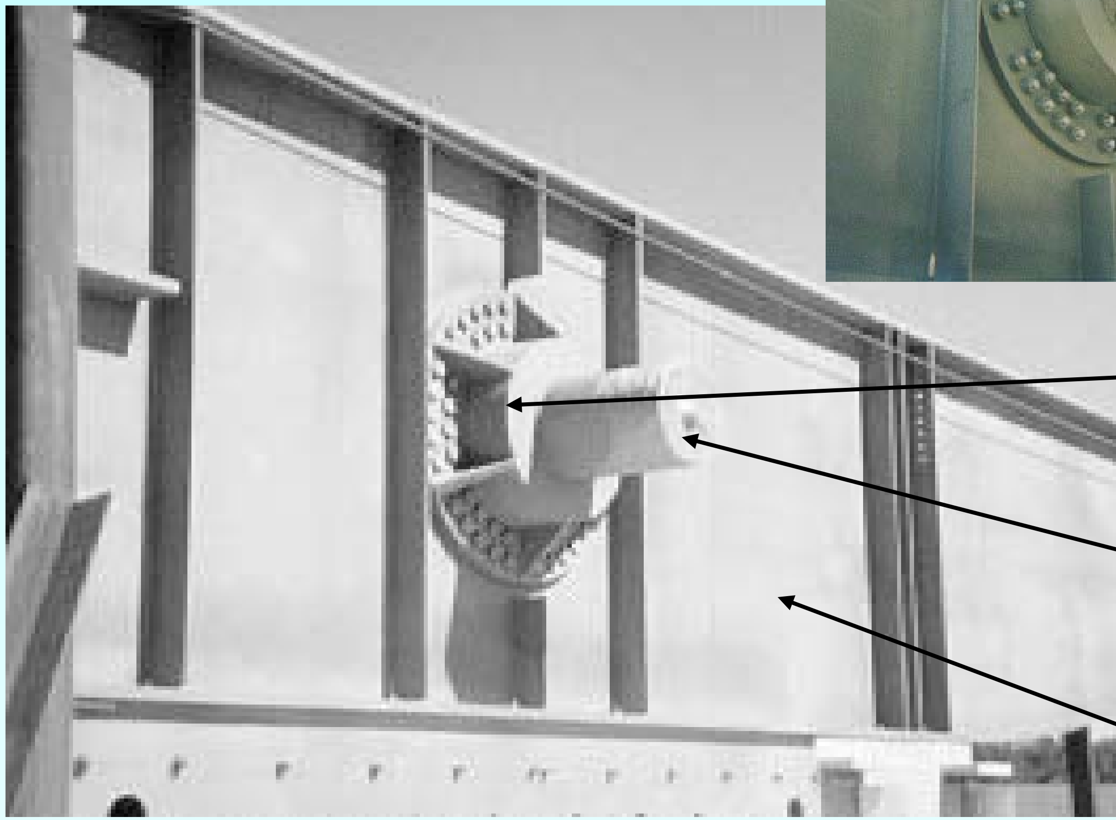
↓

Using the Solution

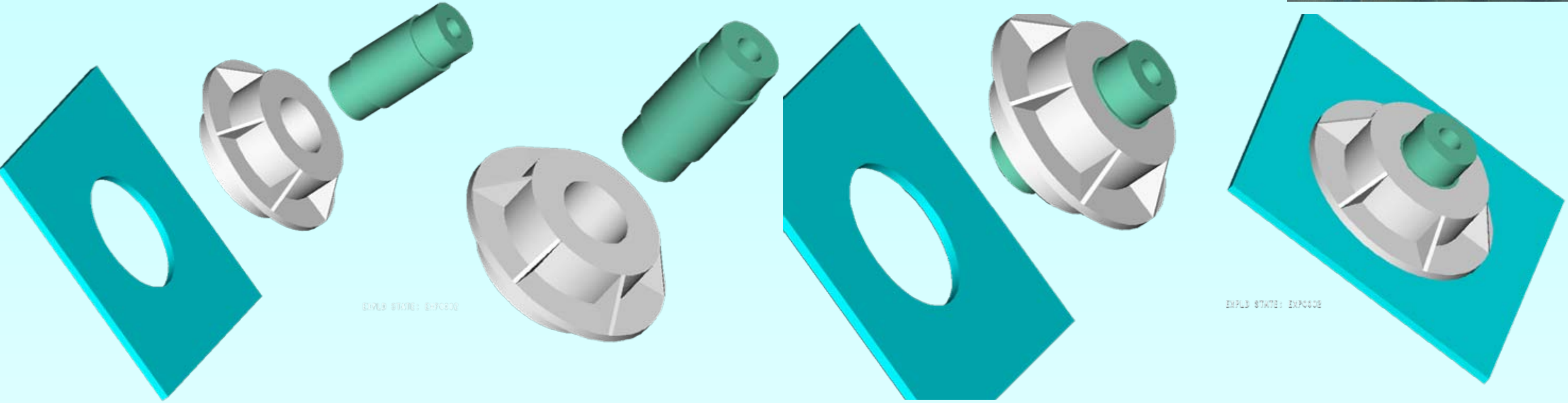
Example of Solving an Engineering Problem

Bascule Bridge THG

Bascule Bridge THG



Trunnion-Hub-Girder Assembly Procedure



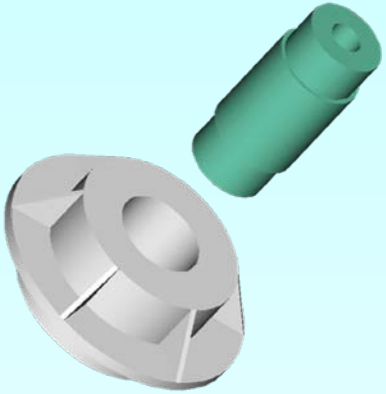
Step1. Trunnion immersed in dry-ice/alcohol

Step2. Trunnion warm-up in hub

Step3. Trunnion-Hub immersed in dry-ice/alcohol

Step4. Trunnion-Hub warm-up into girder

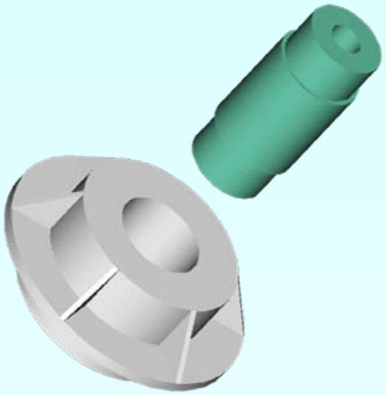
Problem



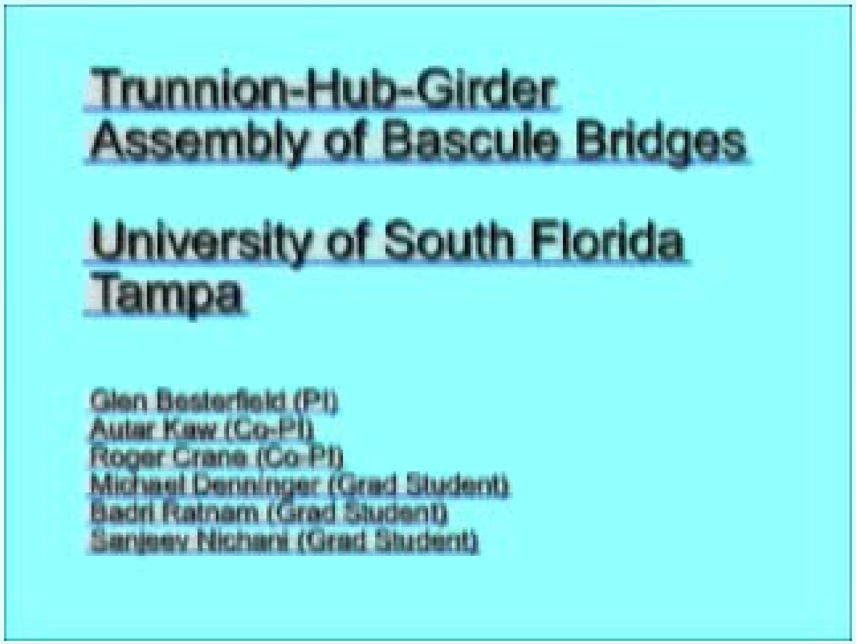
After Cooling, the Trunnion Got Stuck in Hub

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

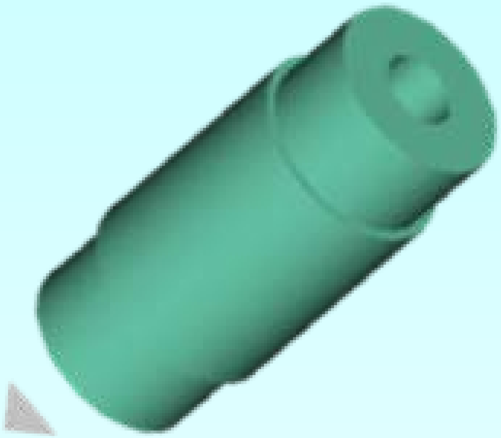


Unplugged Version

VH1 Version

Consultant calculations

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



$$D = 12.363''$$

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

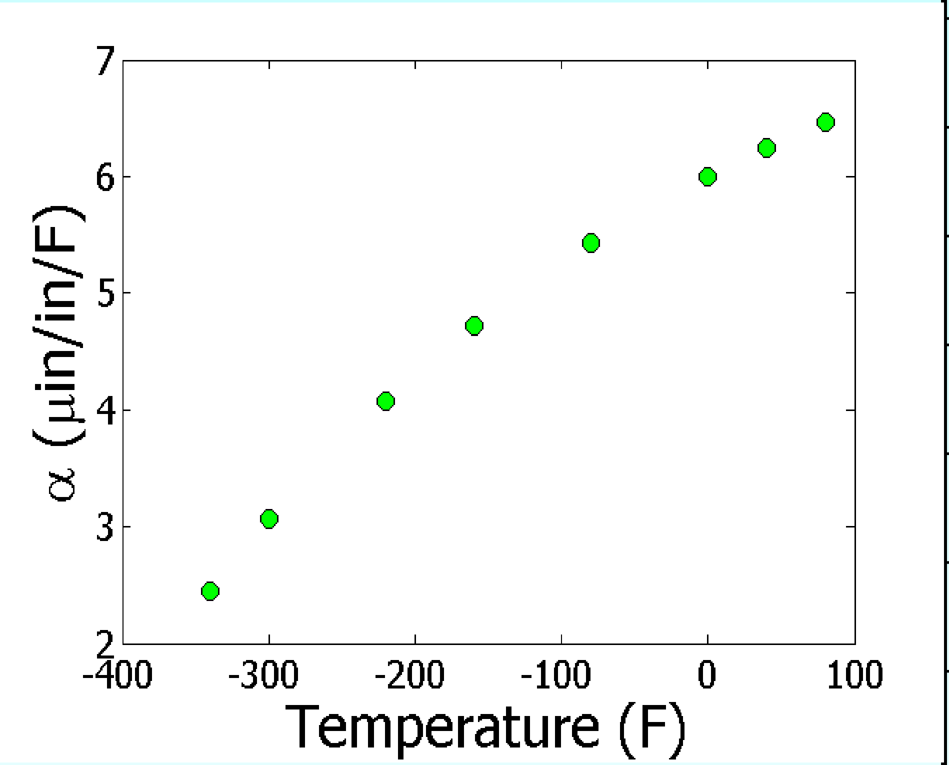
$$\Delta T = -108 - 80 = -188^{o}F$$

$$\Delta D = (12.363)(6.47 \times 10^{-6})(-188)$$

$$= -0.01504''$$

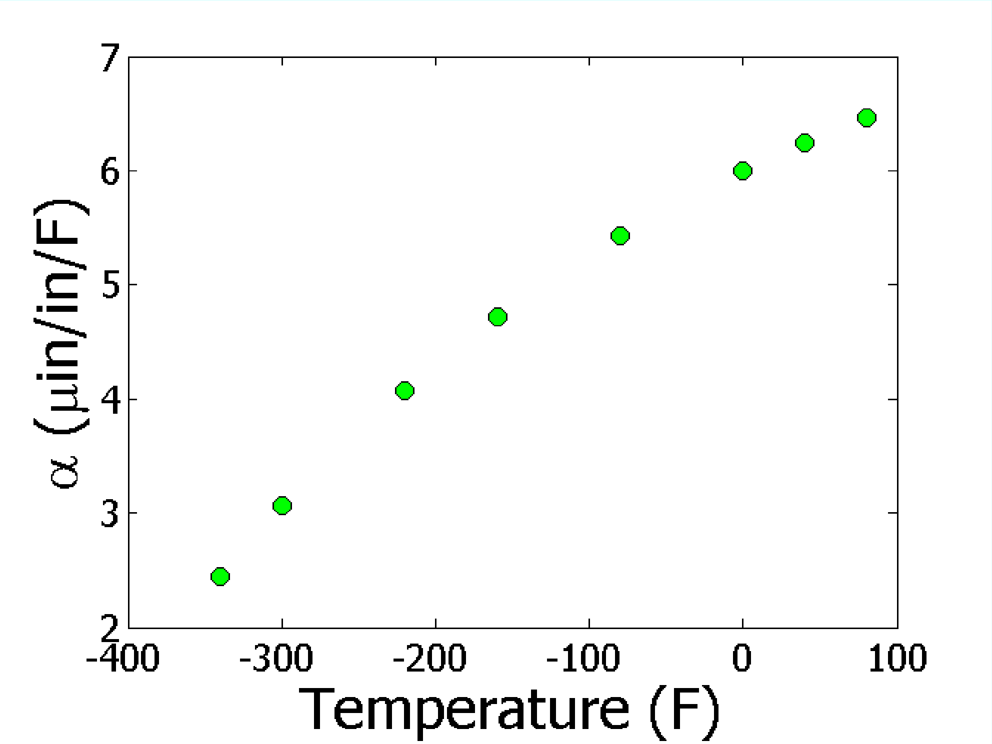
Is the formula used correct?

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



T(°F)	α (μin/in/°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

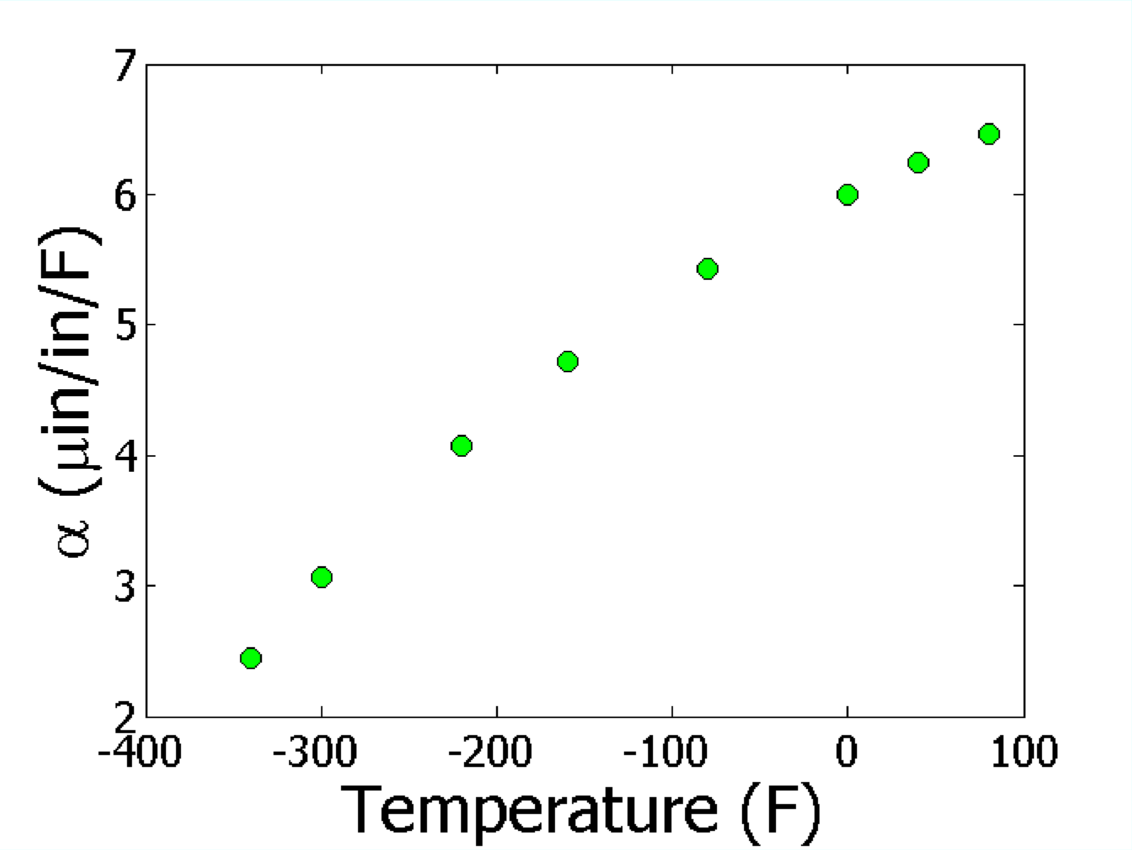


$$\Delta D = D\int_{T_a}^{T_c} \alpha(T)\,dT$$

Can You Roughly Estimate the Contraction?

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

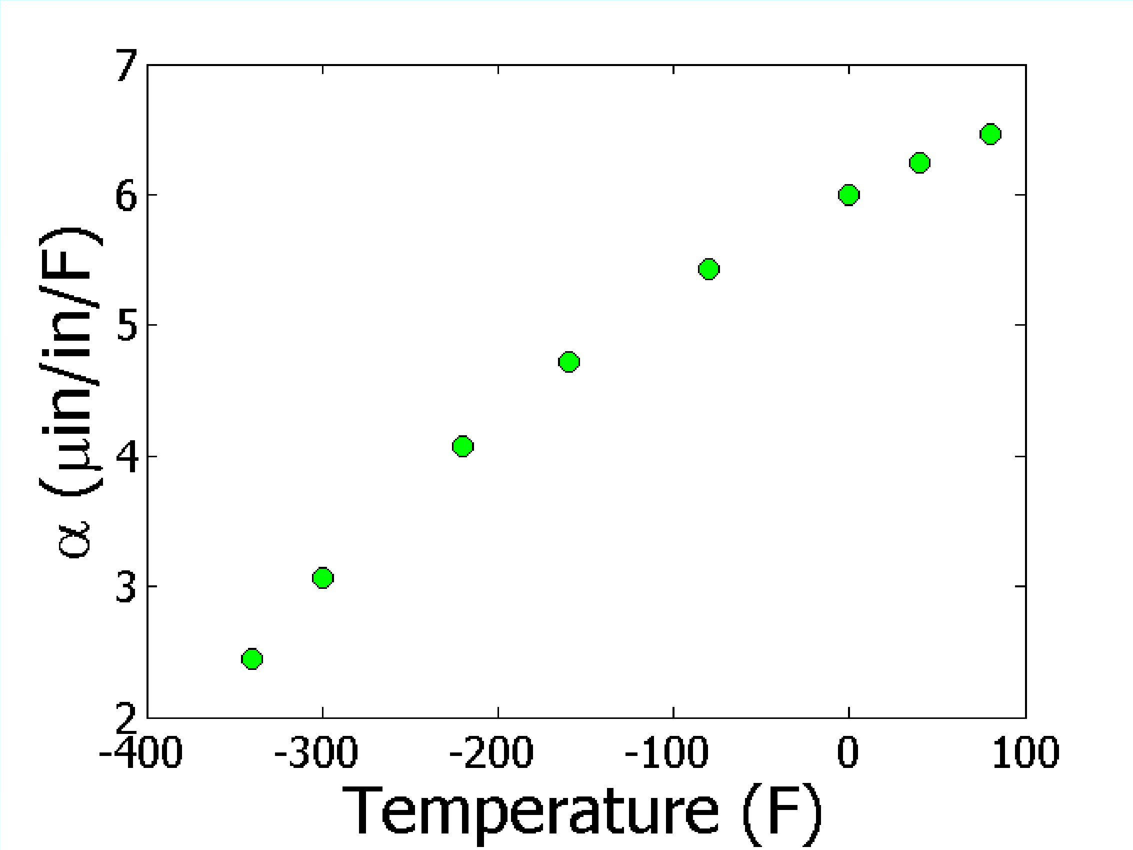
T_a=80^{o}F; T_c=-108^{o}F; D=12.363”



Can You Find a Better Estimate for the Contraction?

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

$T_a = 80^oF$
$T_c = -108^oF$
$D = 12.363''$

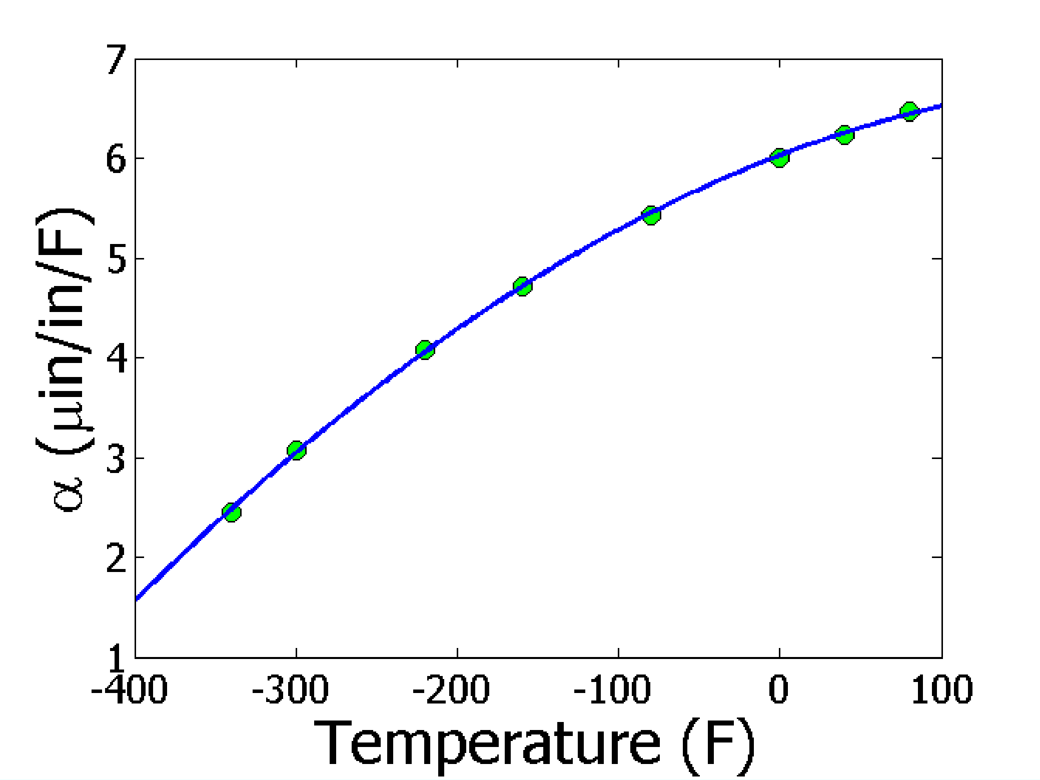


Estimating Contraction Accurately

Change in diameter (ΔD) by cooling it in dry ice/alcohol is given by

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

$T_a = 80^oF$
$T_c = -108^oF$
$D = 12.363''$



$$\alpha = -1.2278\times10^{-5}T^2 + 6.1946\times10^{-3}T + 6.0150$$

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

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^{o}F as opposed to the dry-ice/alcohol temperature of -108^{o}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

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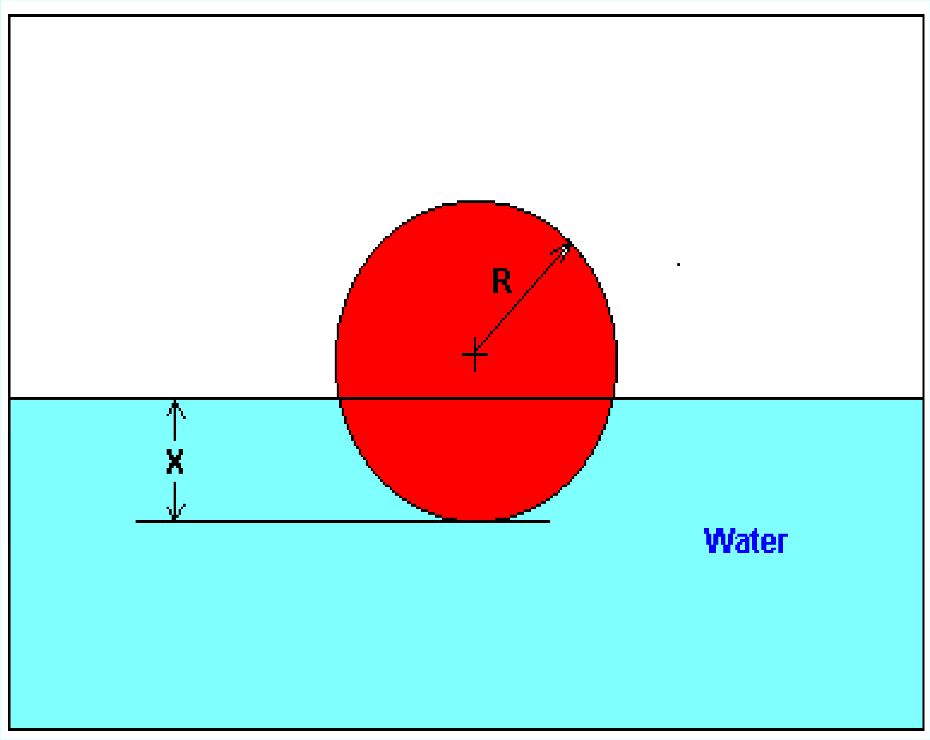
Mathematical Procedures

- 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?



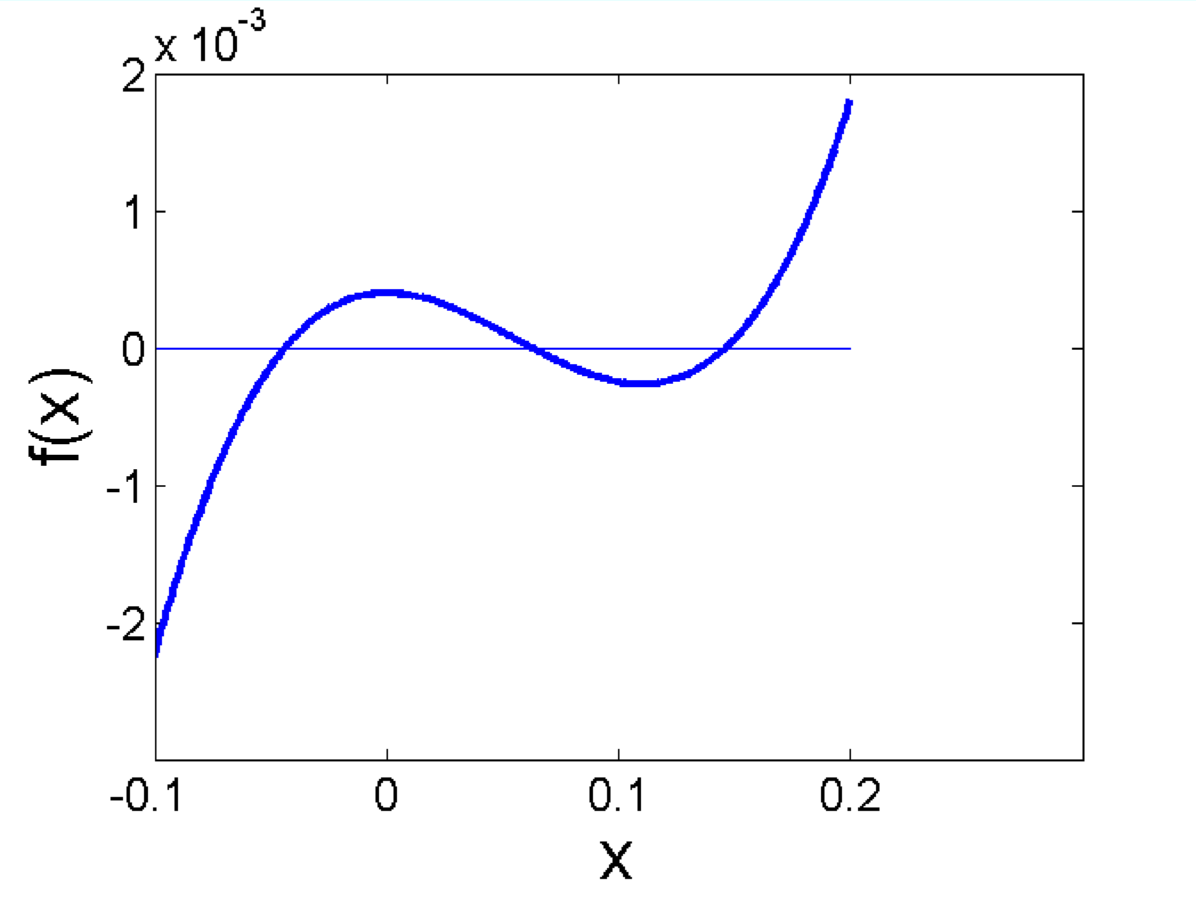
Diameter=0.11m

Specific Gravity=0.6

$$x^3 - 0.165x^2 + 3.993\times10^{-4} = 0$$

Nonlinear Equations

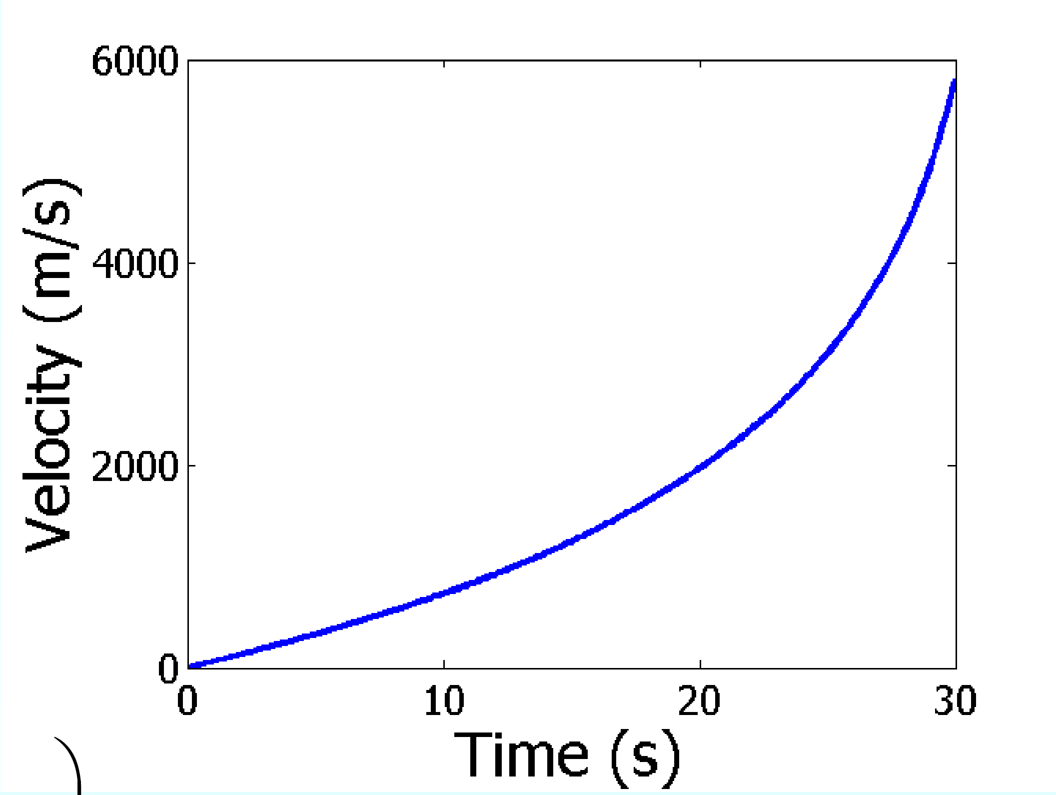
How much of the floating ball is under the water?



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

Differentiation

What is the acceleration at t=7 seconds?



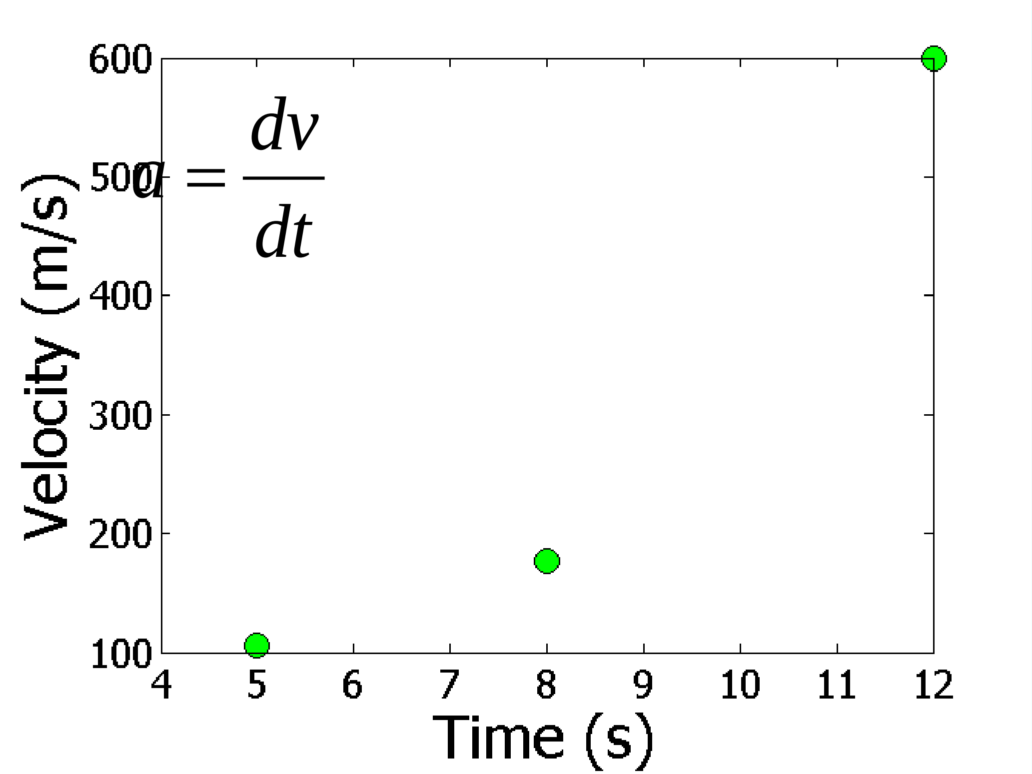
$$v(t) = 2200 \ln\left(\frac{16\times10^4}{16\times10^4 - 5000t}\right) - 9.8t$$

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

Differentiation

What is the acceleration at t=7 seconds?

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



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

Simultaneous Linear Equations

Find the velocity profile, given

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

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

Three simultaneous linear equations

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

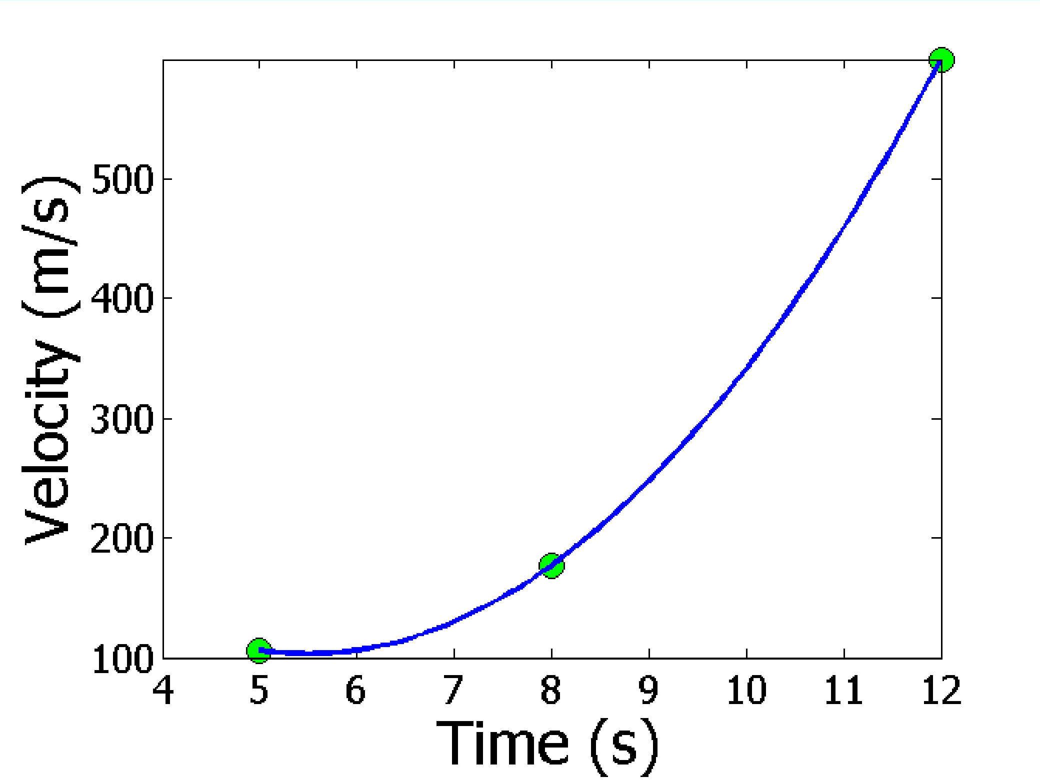
$$64a + 8b + c = 177$$

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

Interpolation

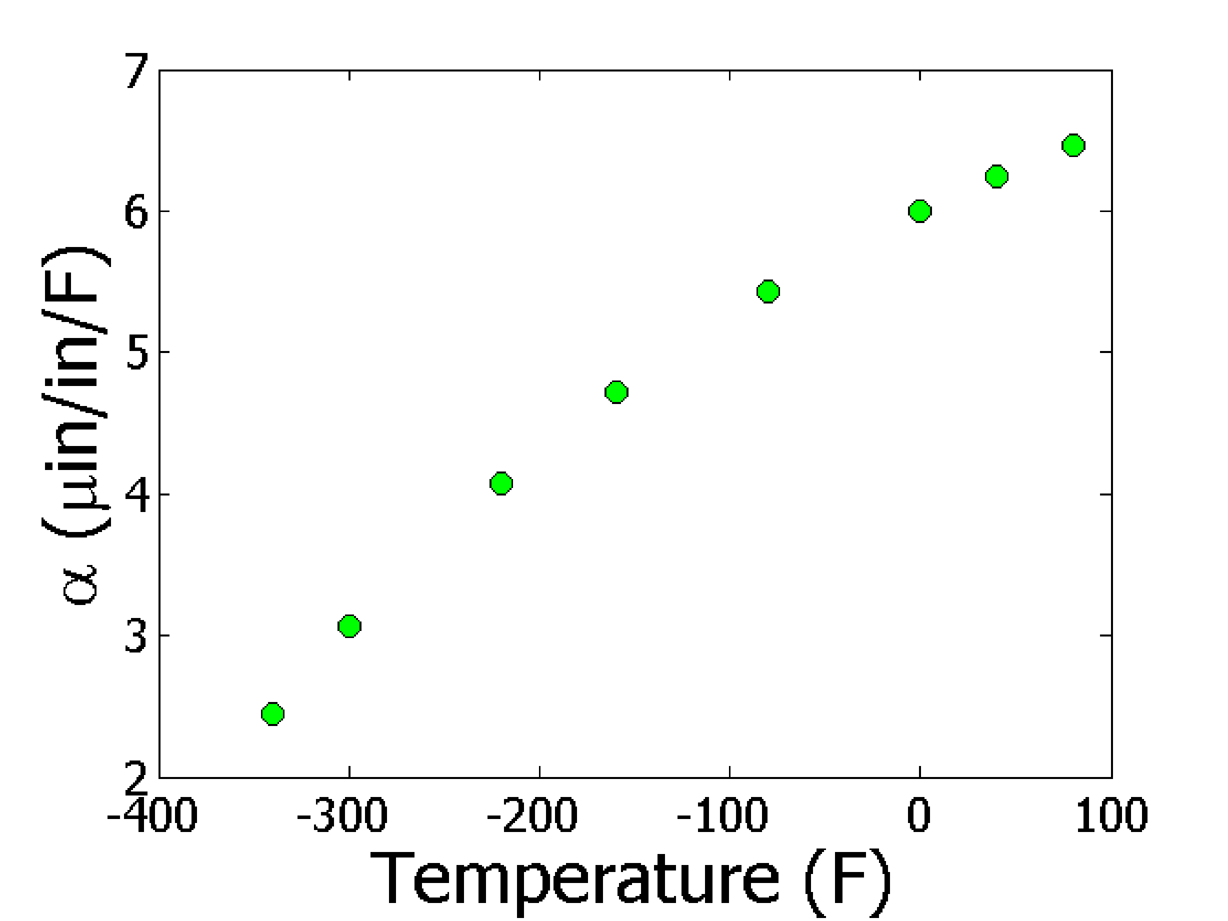
What is the velocity of the rocket at t=7 seconds?

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

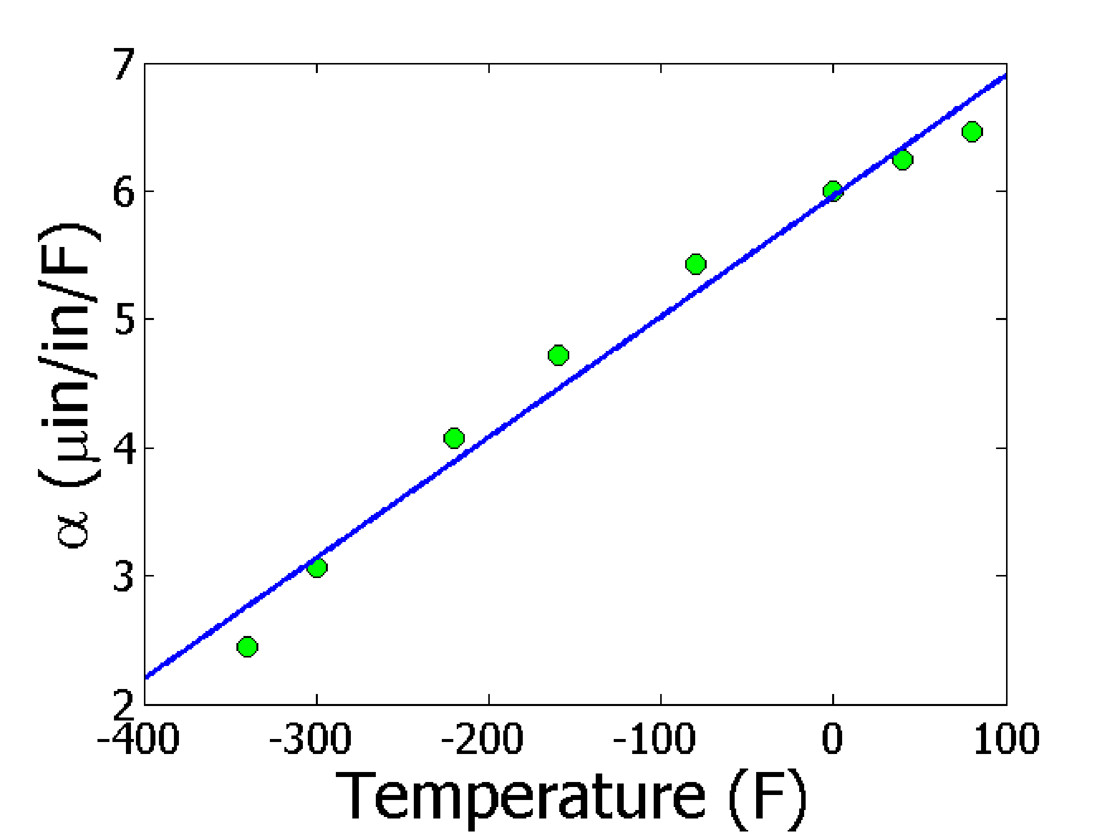


Regression

Thermal expansion coefficient data for cast steel



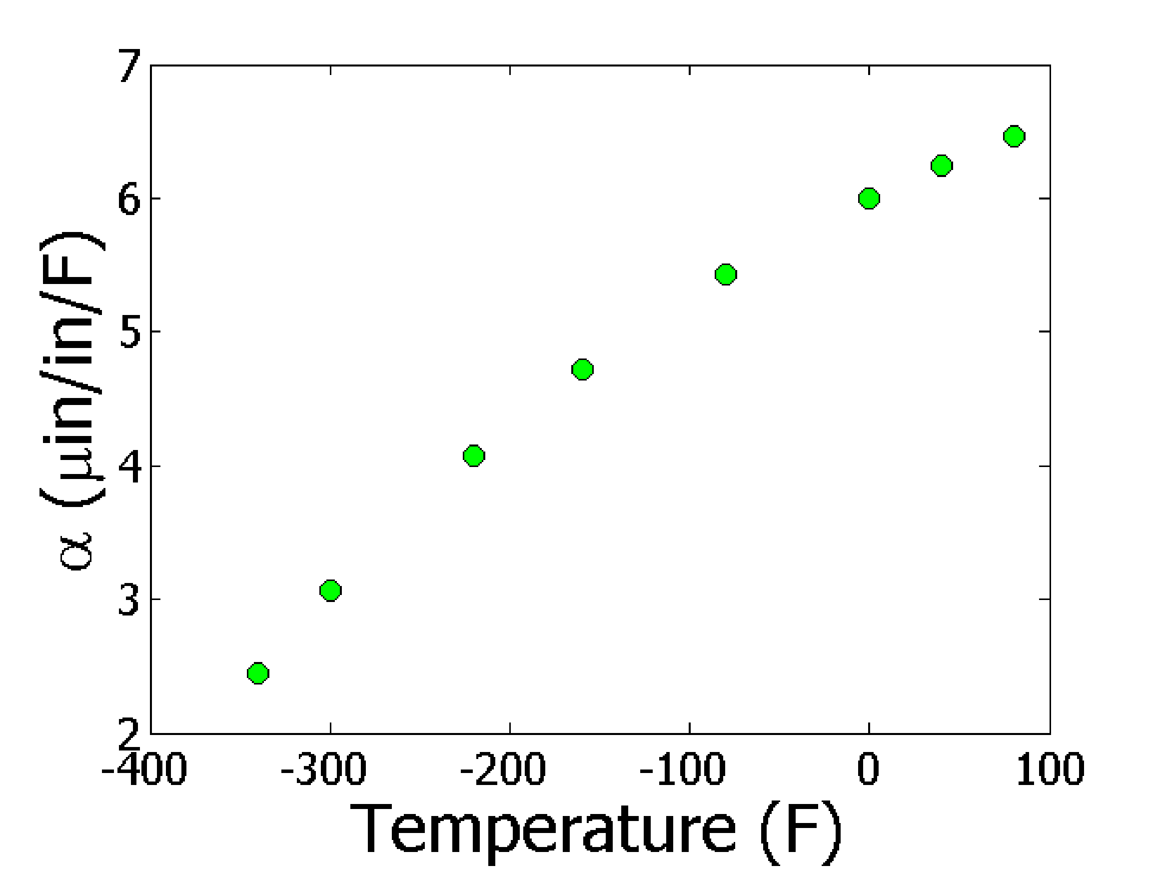
Regression (cont)



Integration

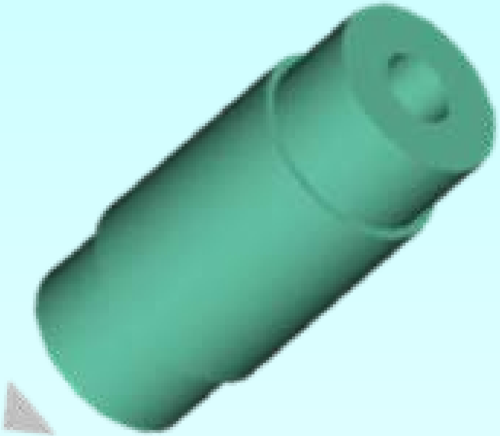
Finding the diametric contraction in a steel shaft when dipped in liquid nitrogen.

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



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

THE END