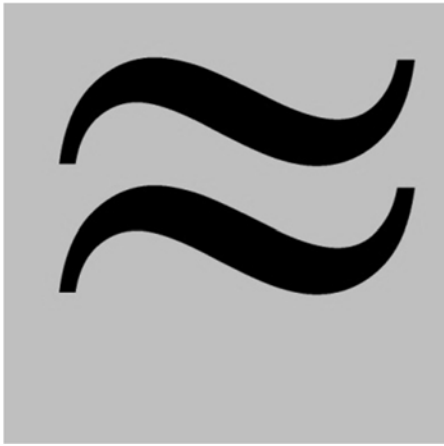
# Introduction to Scientific Computing

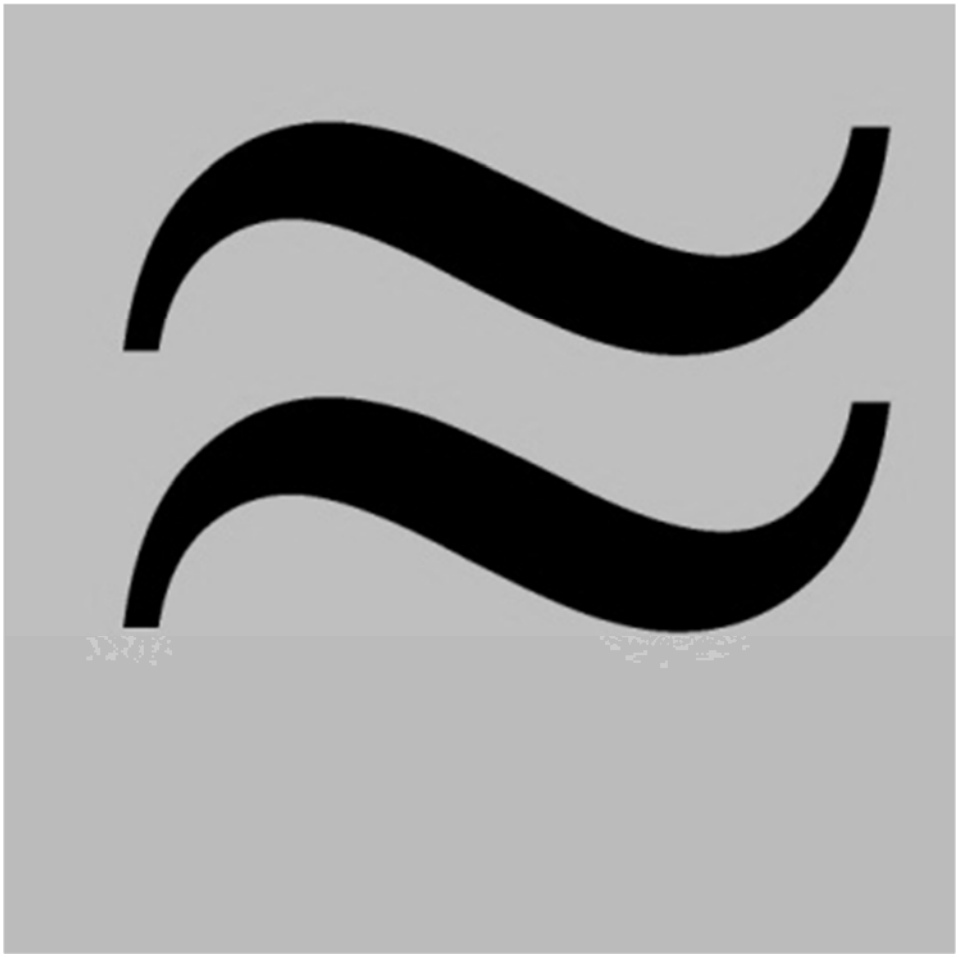
http://nm.MathForCollege.com

Transforming Numerical Methods Education for STEM Undergraduates

- **Welcome to EML3041: Computational Methods.**
- **My name is Dr. Kaw.**
- **Sign the attendance sheet as it gets passed around.**
- **Have you gotten your textbooks and TI30Xa calculator!**
- **Introduce yourself to the person on your left and right. Say one thing (nothing personal) about yourself to them.**
- **At home, go thru the CANVAS modules.**
- **All is well that ends well; well-begun is half-done.**
- **No cell phones, laptops or other distractions. Daydreamers and sleepers will not be disturbed.**
- **First HW is due on next Monday.**



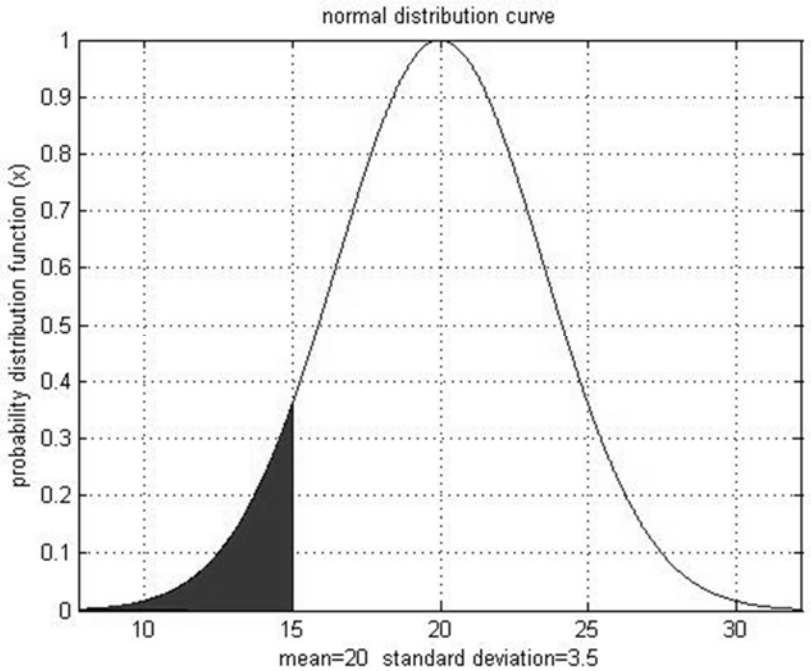
# Why use Numerical Methods?



# Why use Numerical Methods?

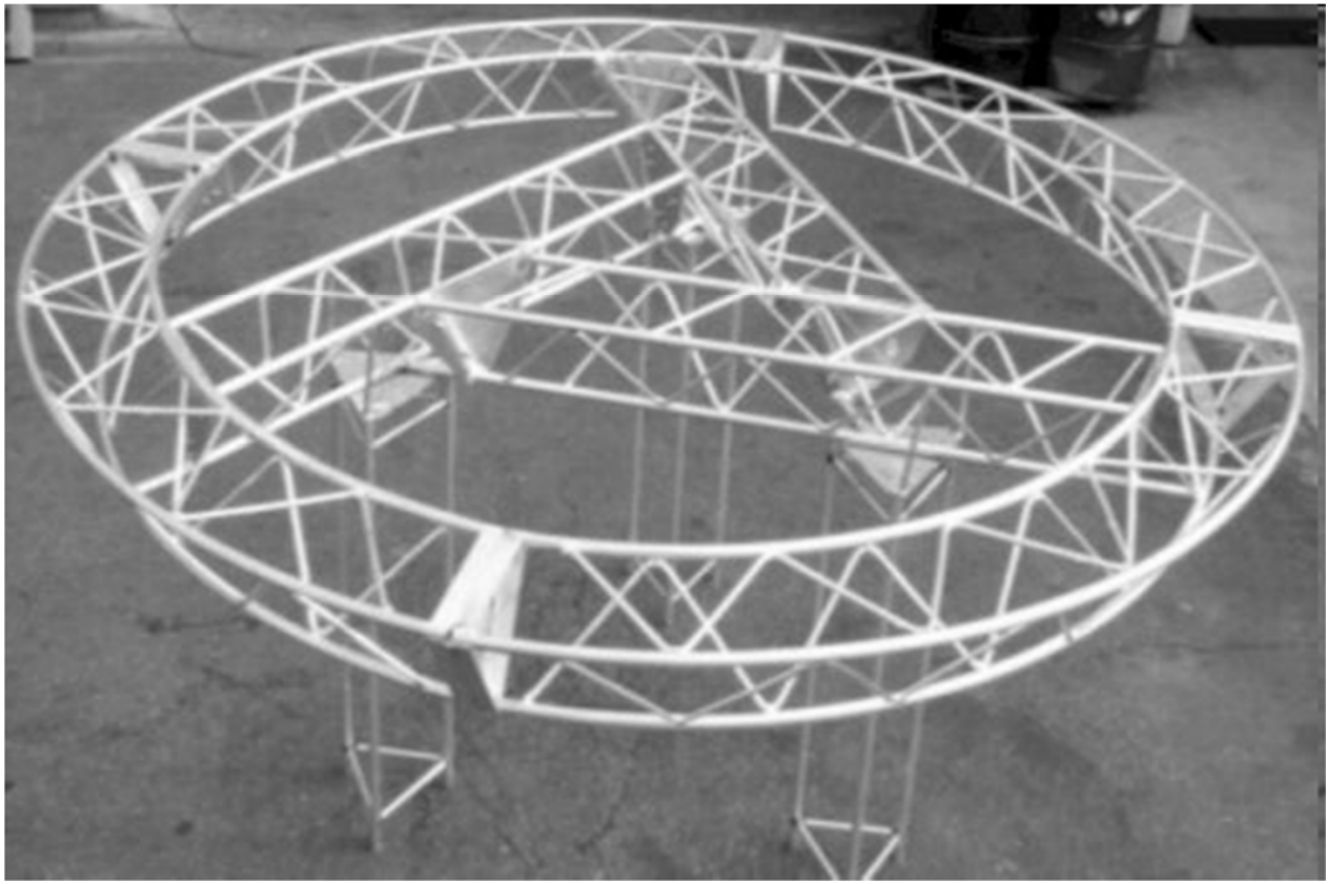
- To solve problems that cannot be solved exactly

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{u^2}{2}} du$$



# Why use Numerical Methods?

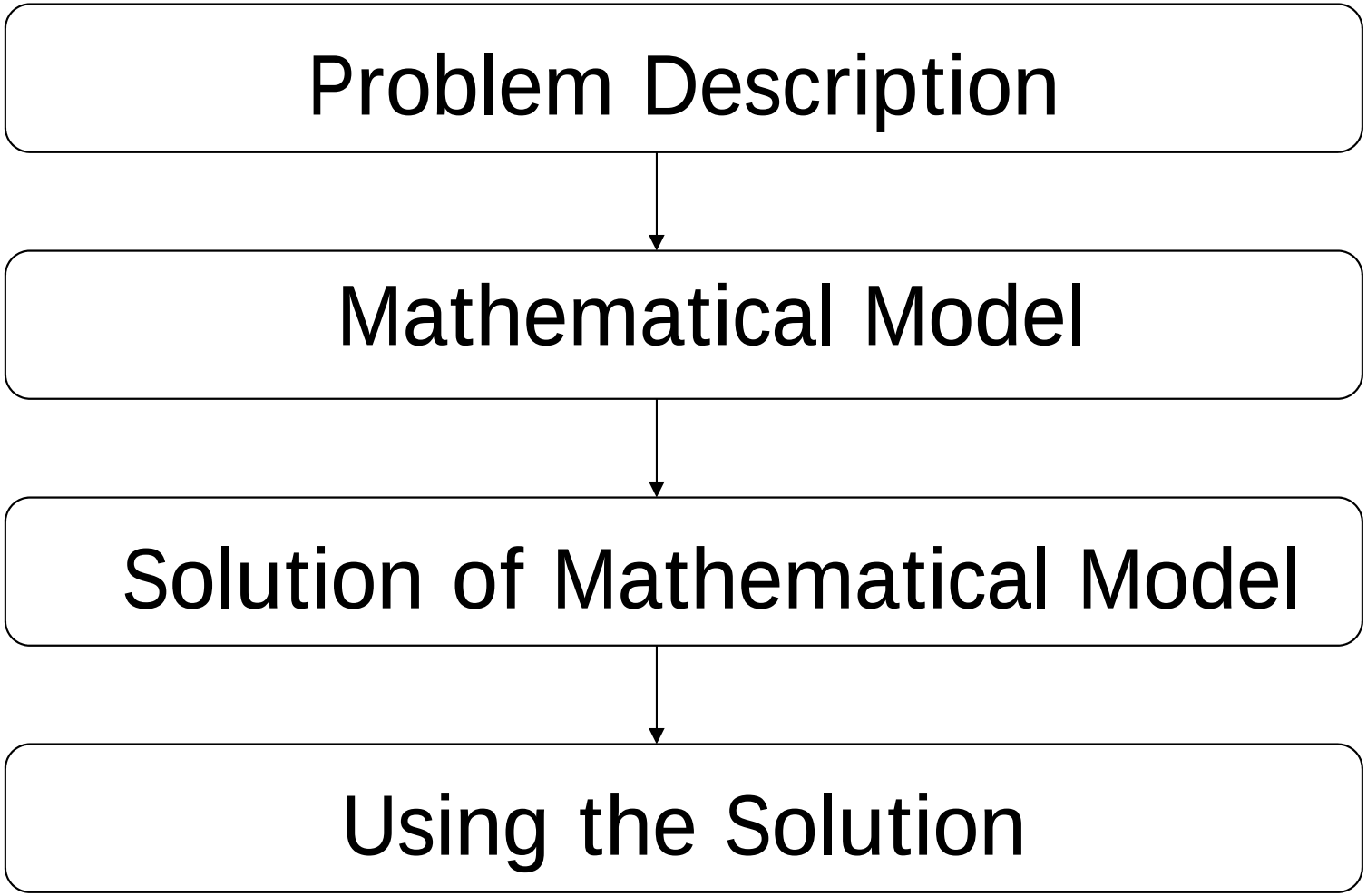
- To solve problems that are intractable to solve exactly!



# Steps in Solving an Engineering Problem

http://nm.MathForCollege.com

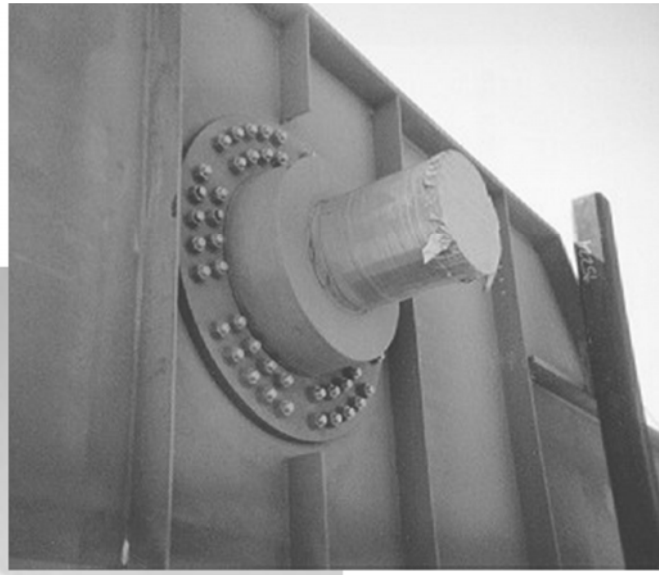
# How do we solve an engineering problem?

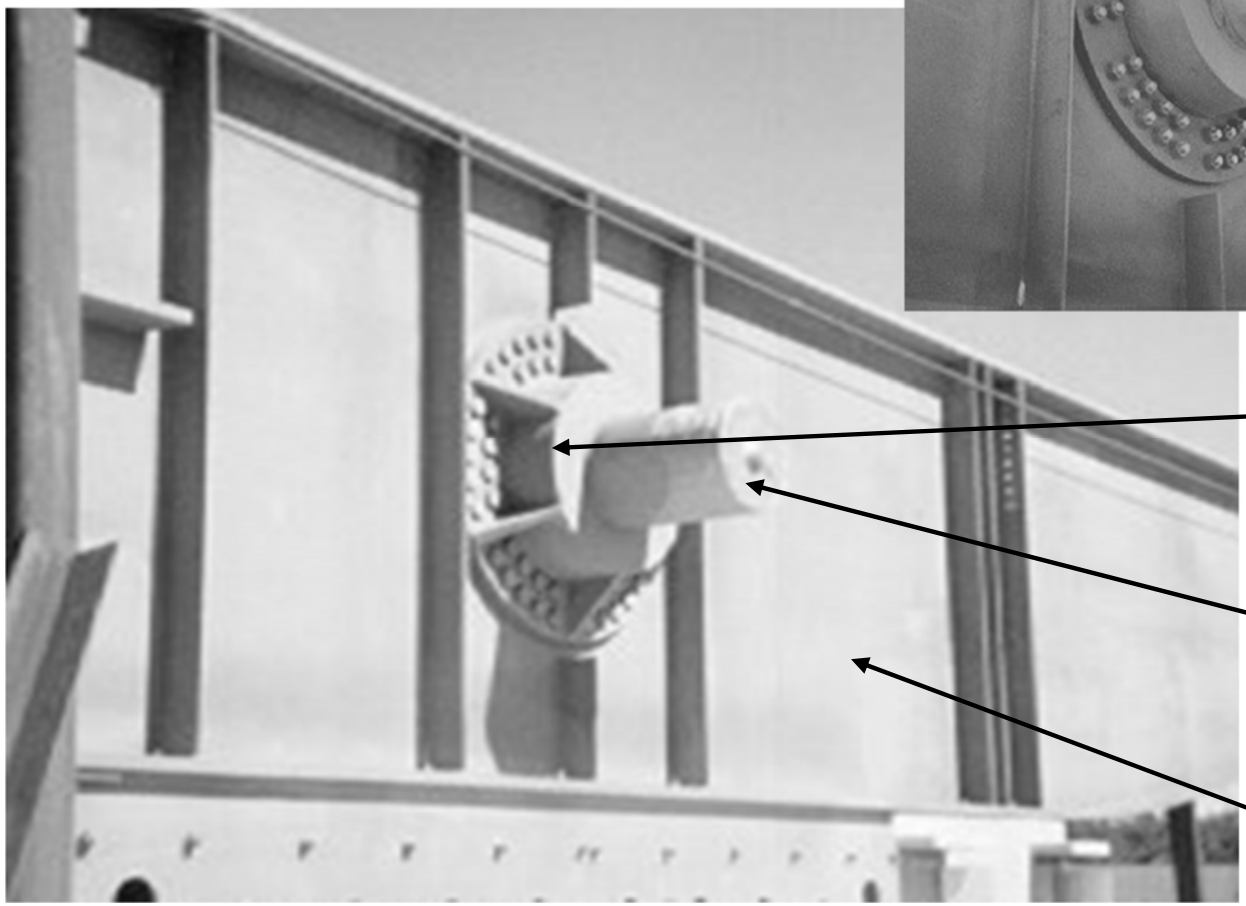


# Example of Solving an Engineering Problem

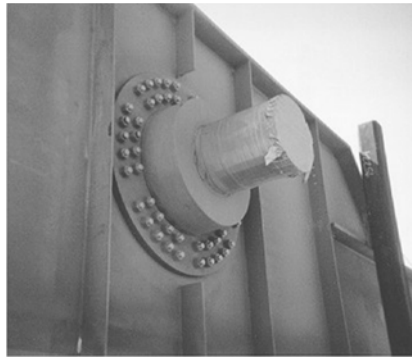
# Bascule Bridge THG

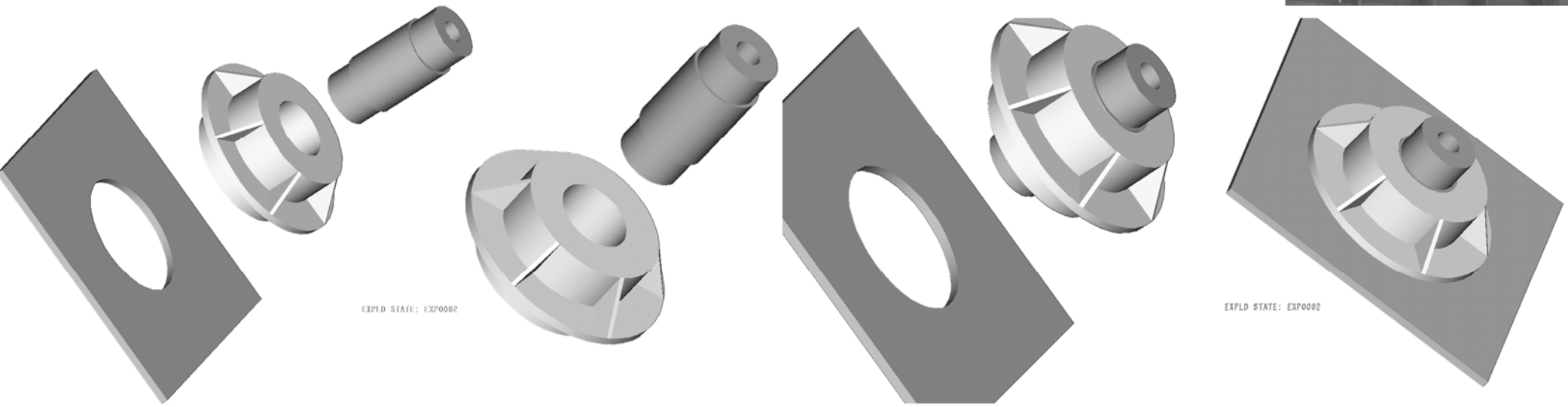
# Bascule Bridge THG





# Trunnion-Hub-Girder Assembly Procedure





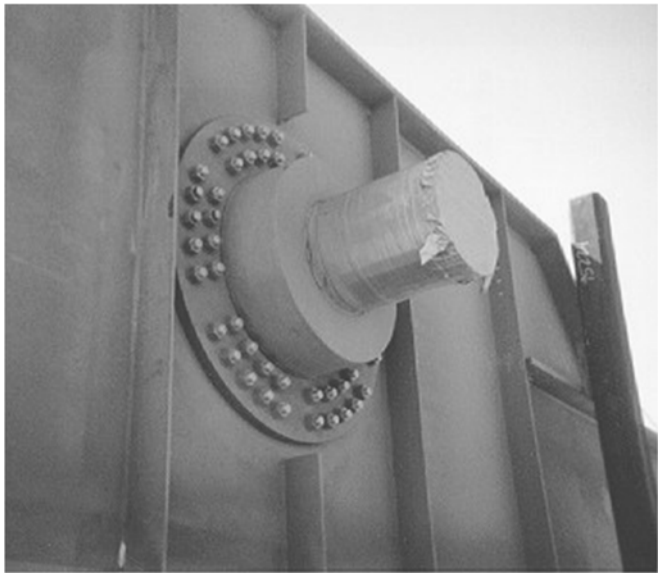

**Step1.** Trunnion immersed in dry-ice/alcohol

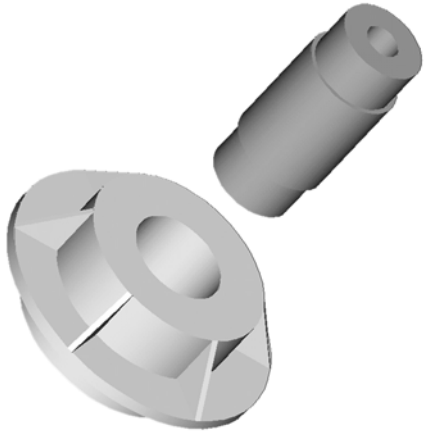
**Step2.** Trunnion warm-up in hub

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

**Step4.** Trunnion-Hub warm-up into girder

# Problem

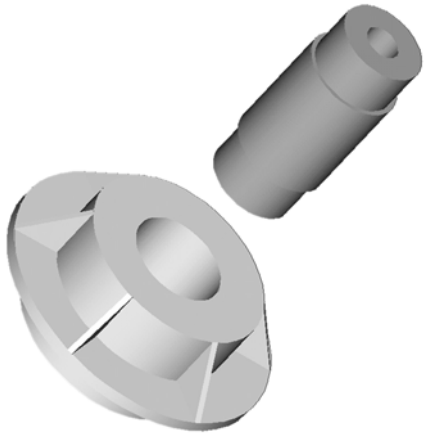




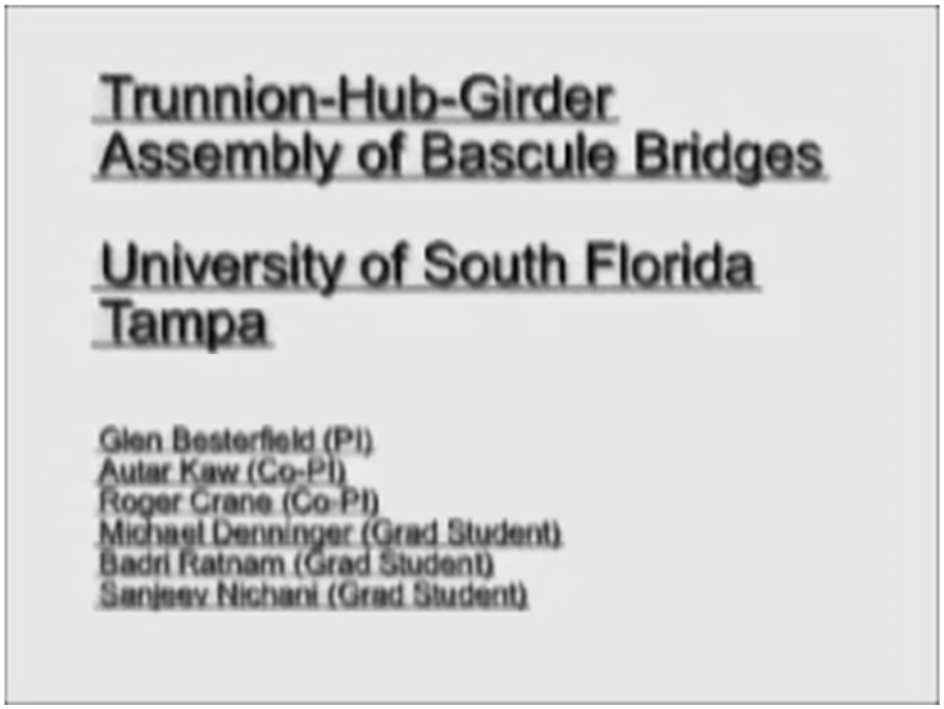
After Cooling, the Trunnion Got Stuck in Hub

# Why did it get stuck?

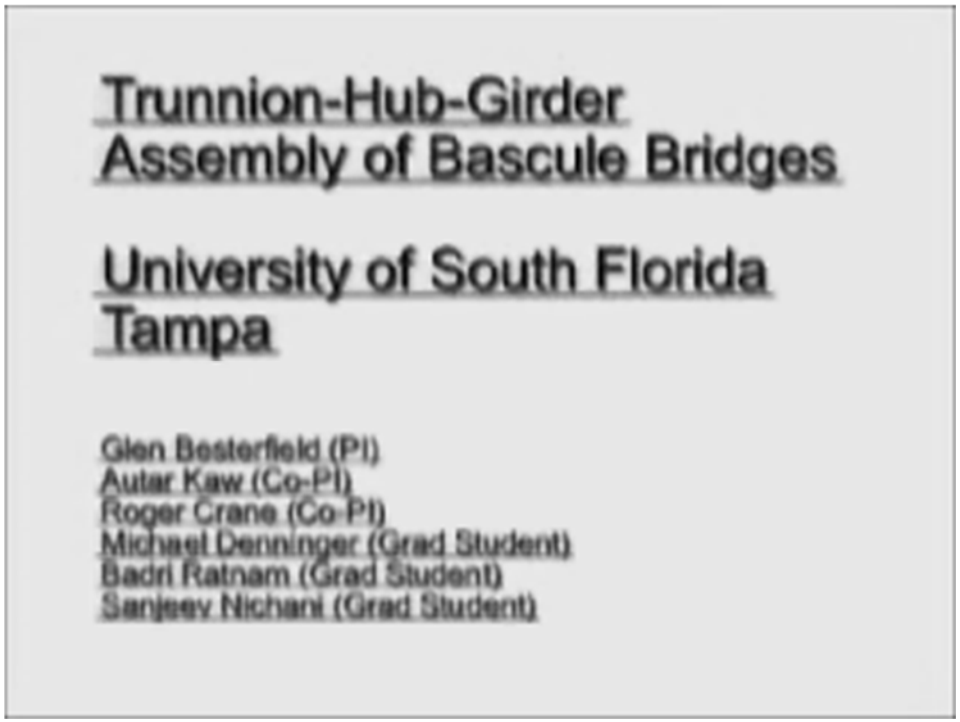
Magnitude of contraction needed in the trunnion was 0.015” or more.  Did it contract enough?



# Video of Assembly Process




Unplugged Version




VH1 Version

# Consultant calculations

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

$$D = 12.363"$$

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

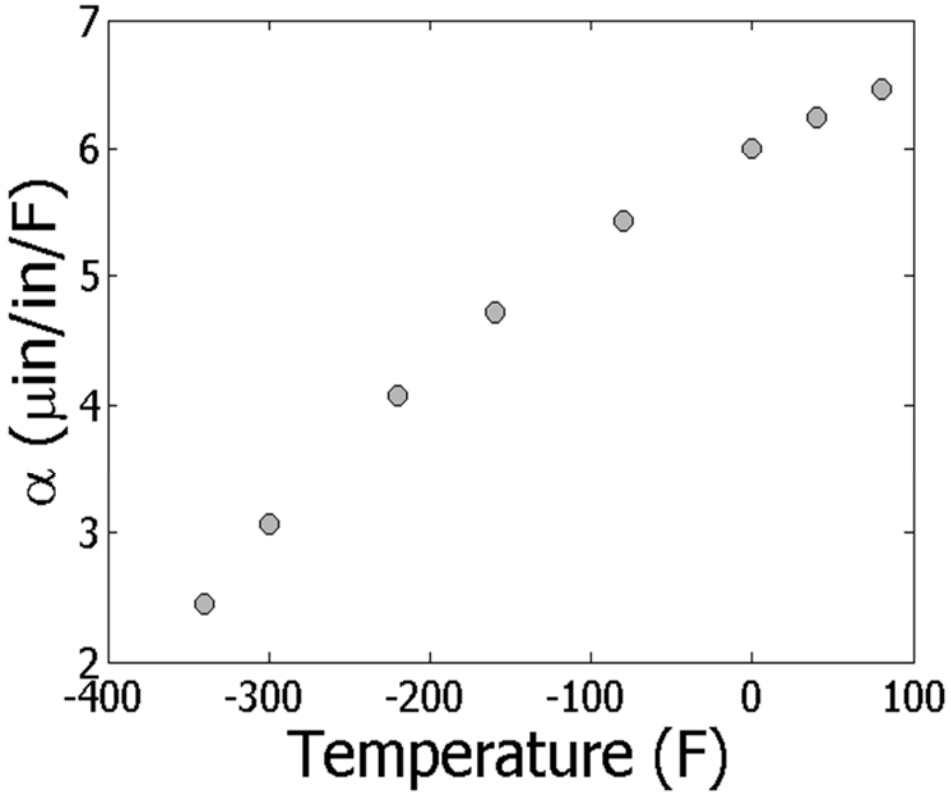
$$\Delta T = -108 - 80 = -188^{o} F$$

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

$$= -0.01504"$$

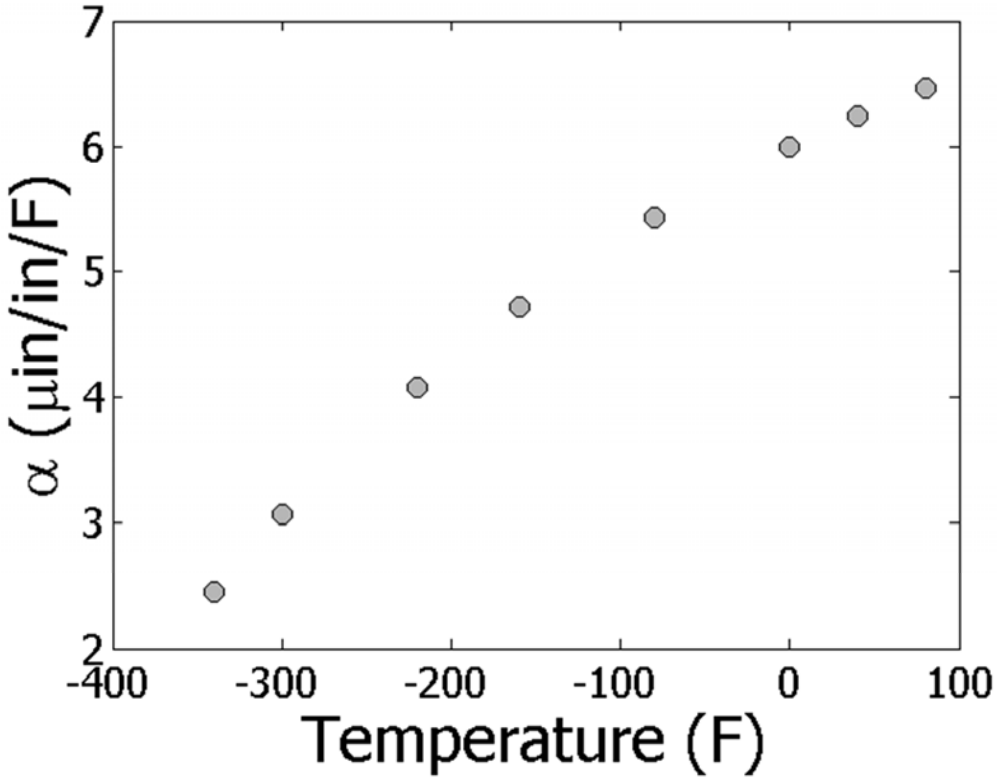
# Is the formula used correct?

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




| 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

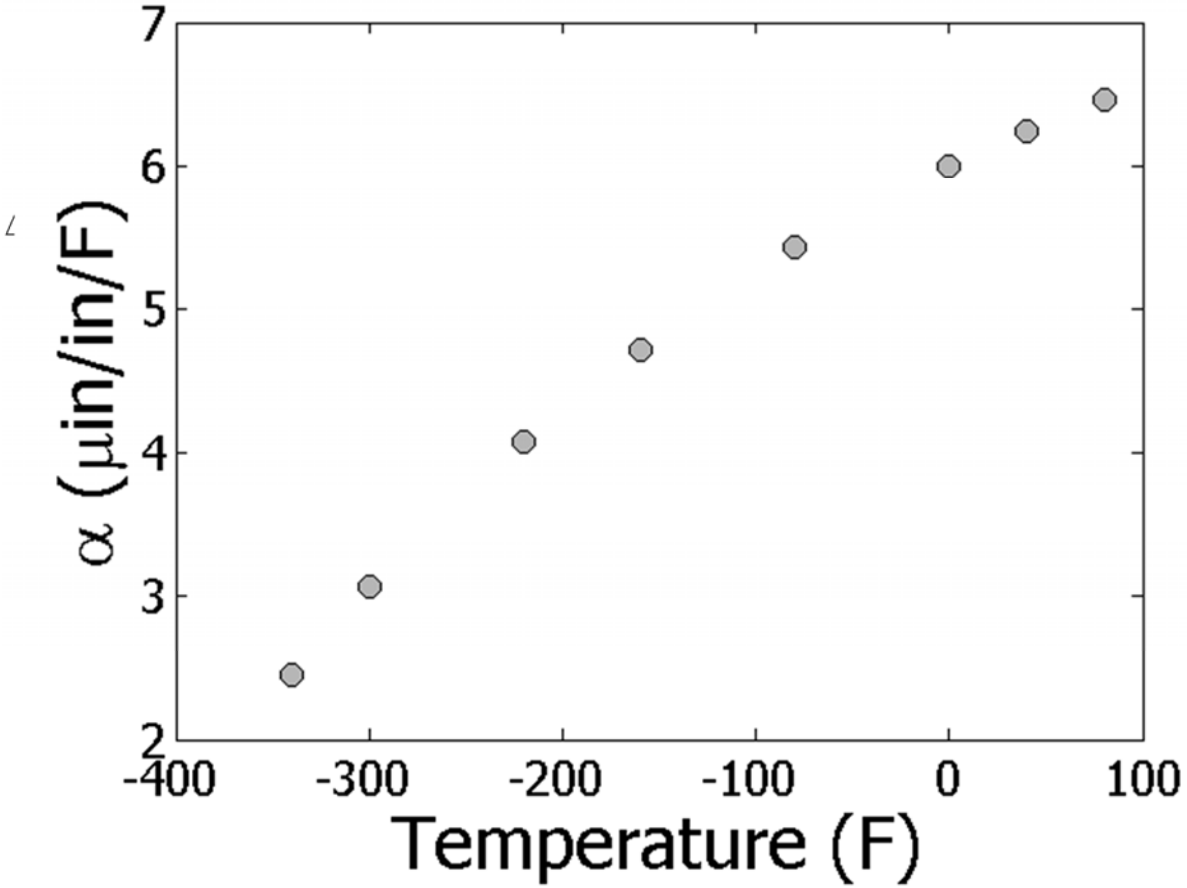



$$\Delta D = D\int_{T_a}^{T_c} \alpha(T)dT$$

# Can You Roughly Estimate the Contraction?

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

$T_a$=80°F; $T_c$=-108°F; D=12.363”



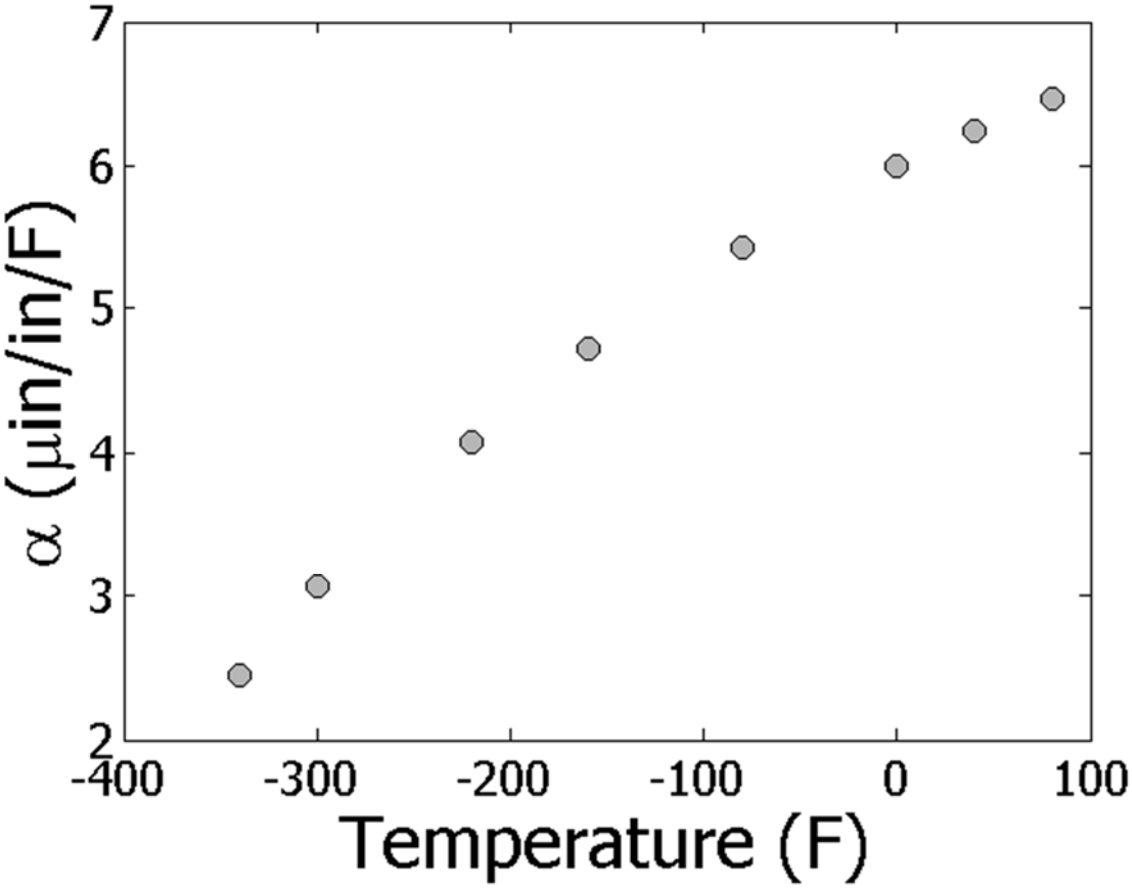
# Can You Find a Better Estimate for the Contraction?

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

$T_a = 80^oF$

$T_c = -108^oF$

$D = 12.363"$



# Estimating Contraction Accurately

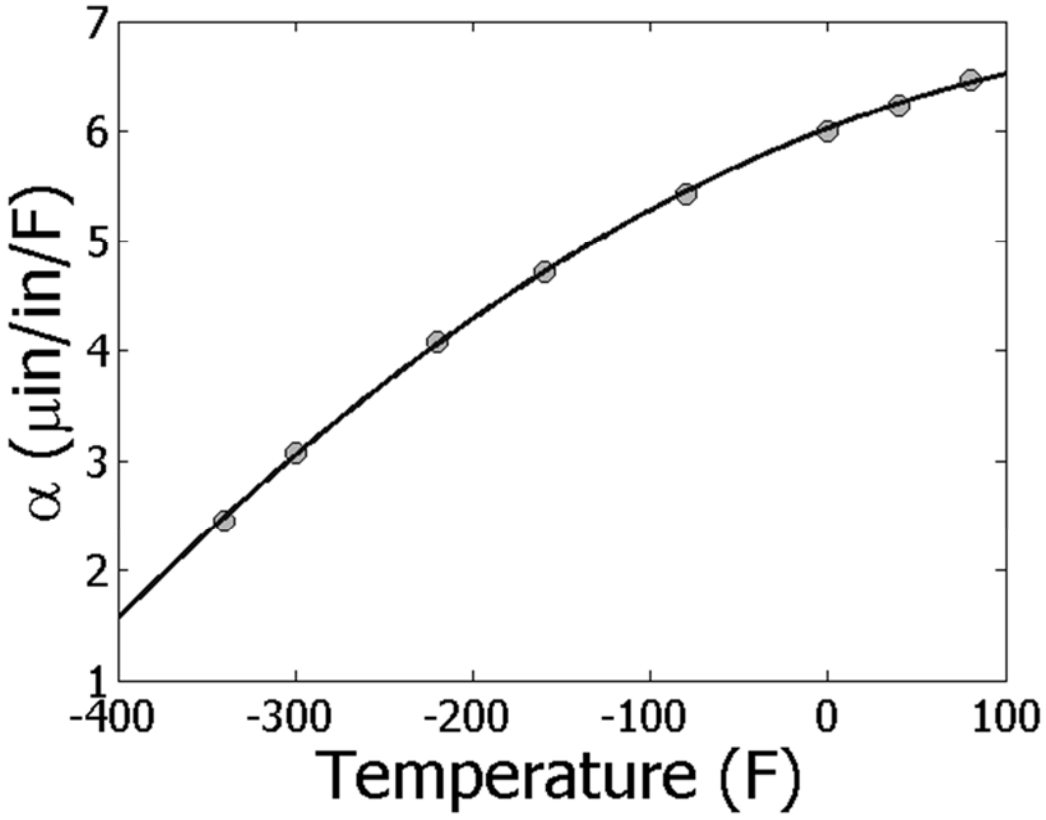
Change in diameter ($\Delta D$) by cooling it in dry ice/alcohol is given by

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

$T_a = 80^oF$

$T_c = -108^oF$

$D = 12.363"$




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

$$\Delta D = -0.0137"$$

# 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

**http://nm.MathForCollege.com**

# Introduction to Numerical Methods

Mathematical Procedures

http://nm.MathForCollege.com

# Mathematical Procedures

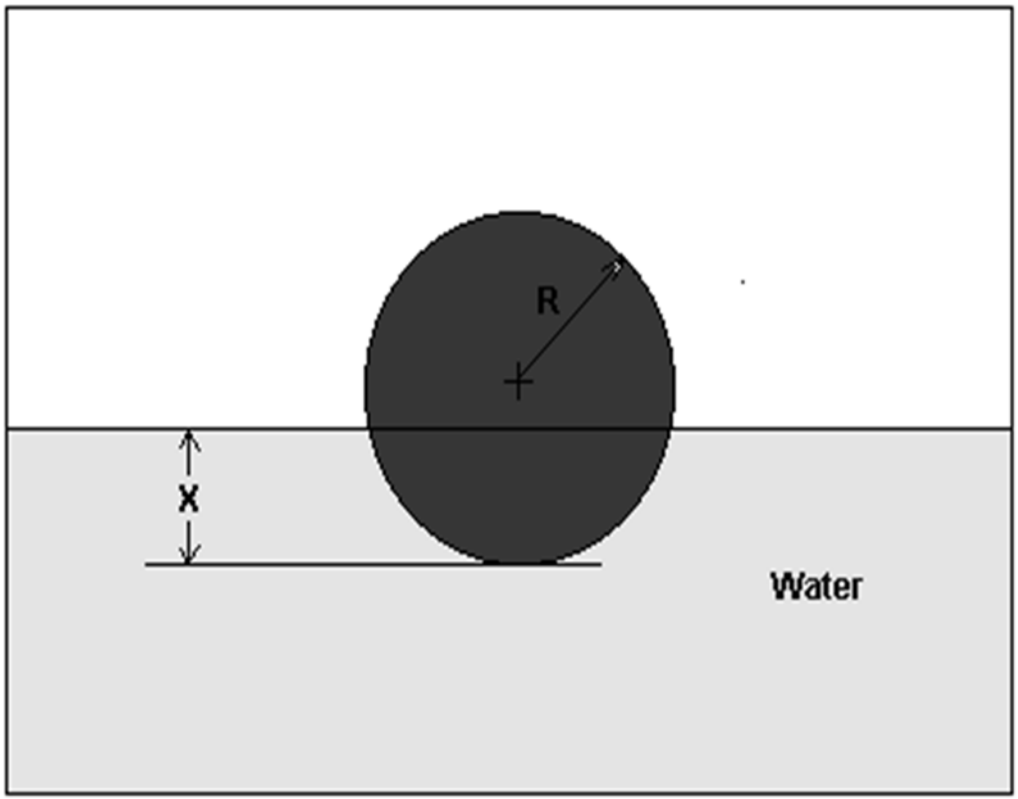
- Nonlinear Equations
- Differentiation
- Simultaneous Linear Equations
- Curve Fitting
  - Interpolation
  - Regression
- Integration
- Ordinary Differential Equations
- Other Advanced Mathematical Procedures:
  - Partial Differential Equations
  - Optimization
  - Fast Fourier Transforms

# Nonlinear Equations

How much of the floating ball is under water?

Diameter = 0.11m

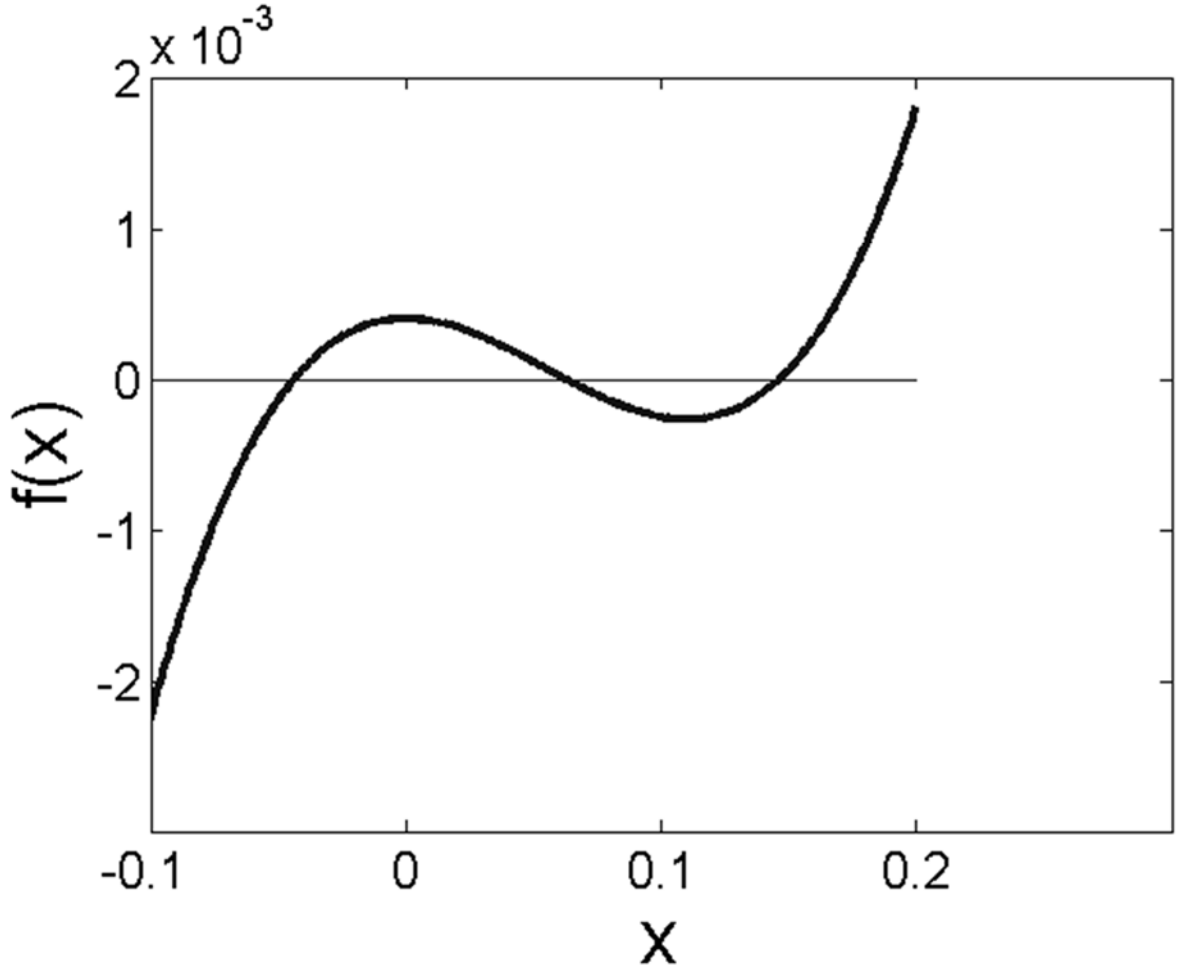
Specific Gravity = 0.6




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

# Nonlinear Equations

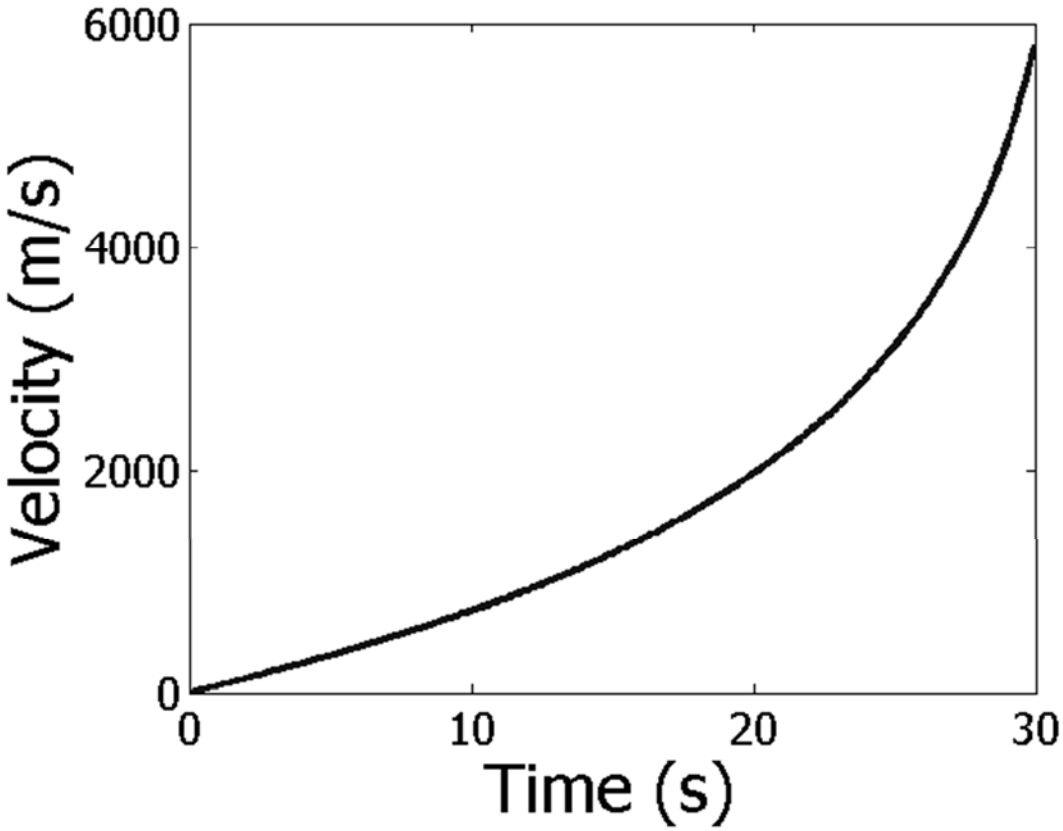
How much of the floating ball is under the water?




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

# Differentiation

What is the acceleration at t=7 seconds?



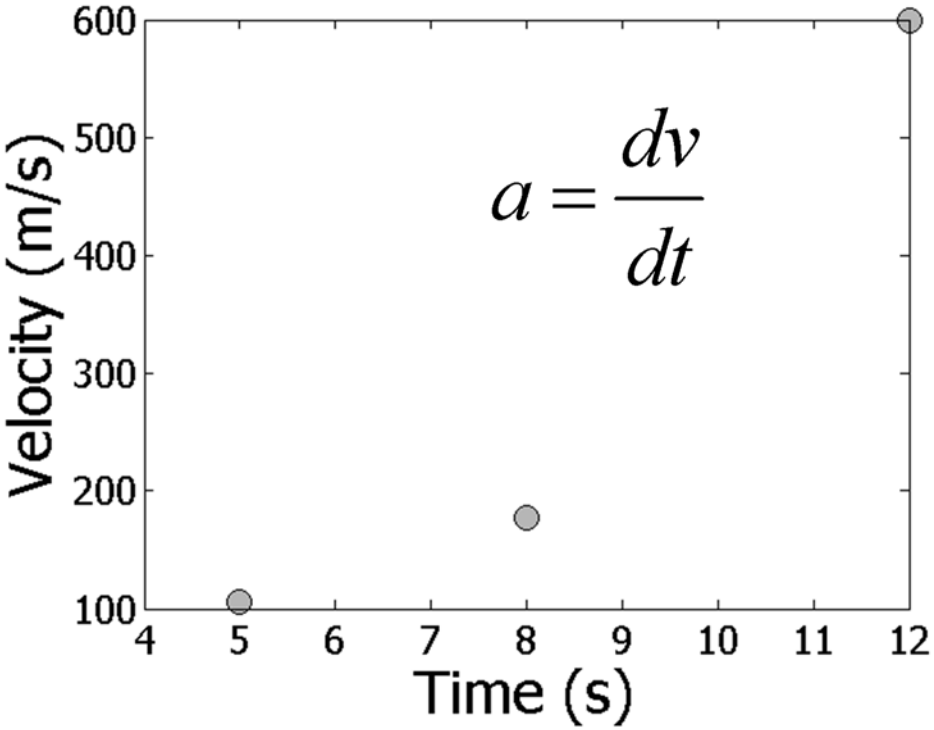

$$v(t) = 2200 \ \ln\left(\frac{16\times10^4}{16\times10^4 - 5000t}\right) - 9.8t$$

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

# Differentiation

What is the acceleration at t=7 seconds?

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



# Simultaneous Linear Equations

Find the velocity profile, given

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

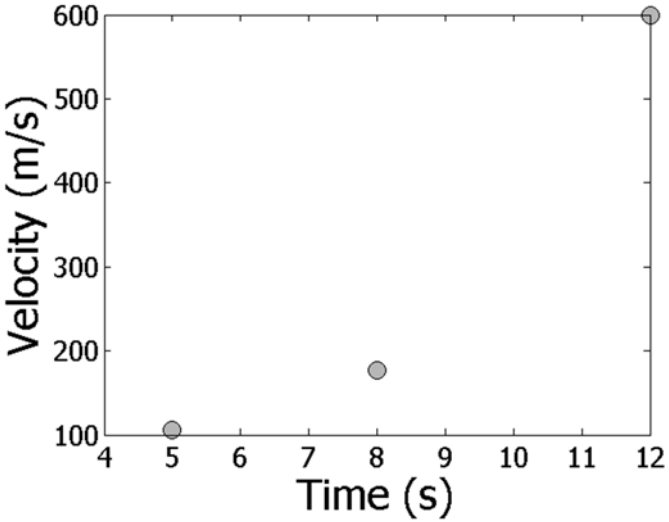
$$v(t) = at^2 + bt + c,\ 5 \le t \le 12$$

Three simultaneous linear equations

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

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

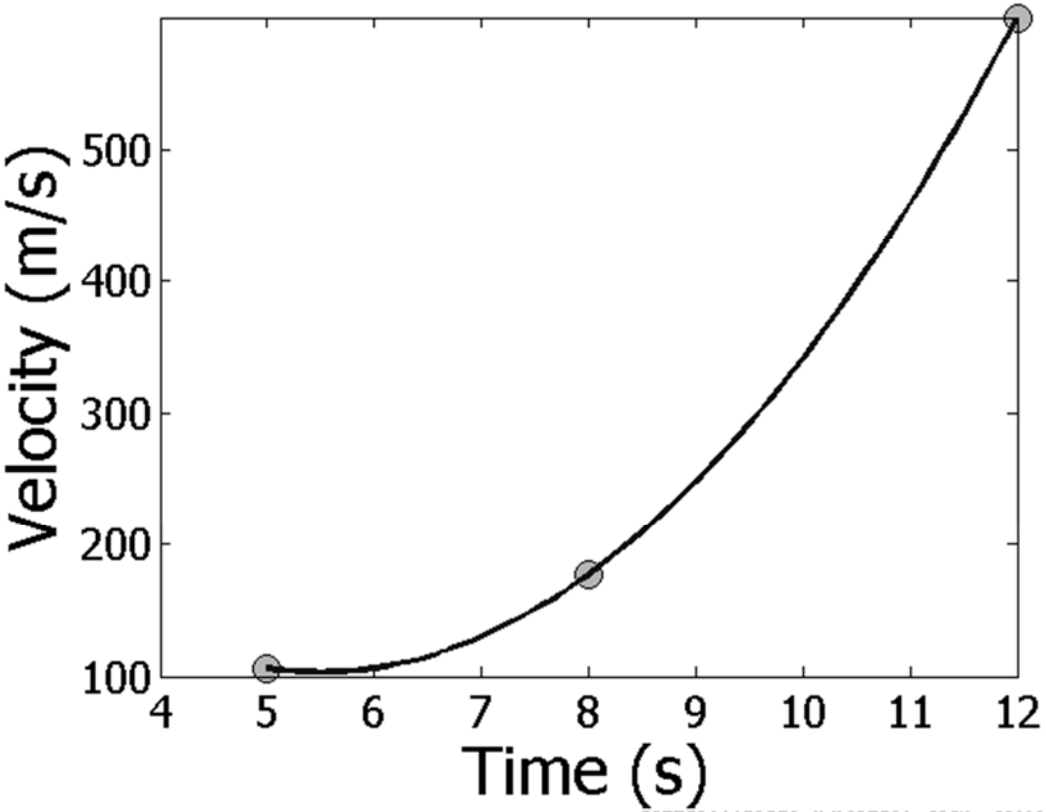
$$144a + 12b + c = 600$$



# Interpolation

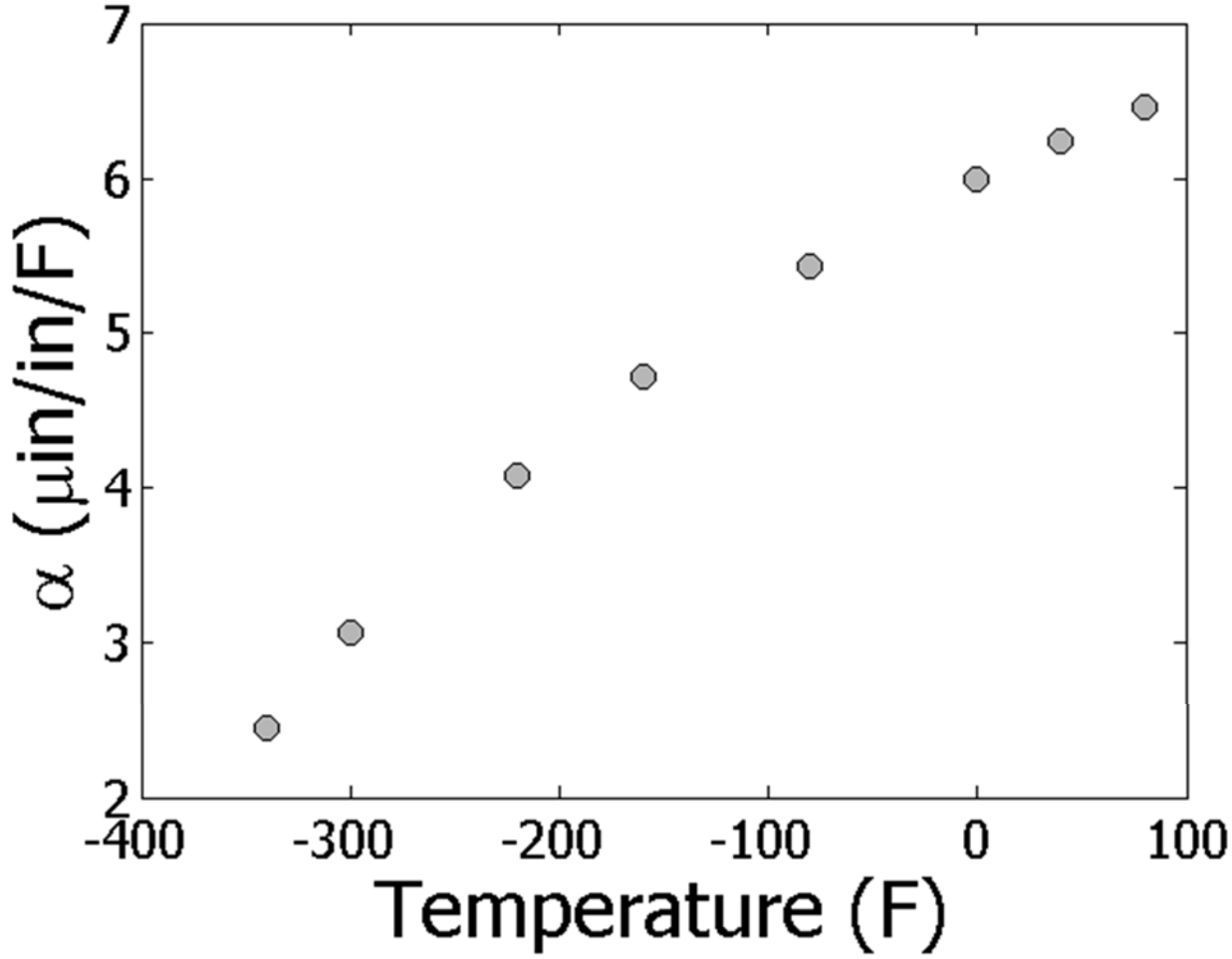
What is the velocity of the rocket at t=7 seconds?

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

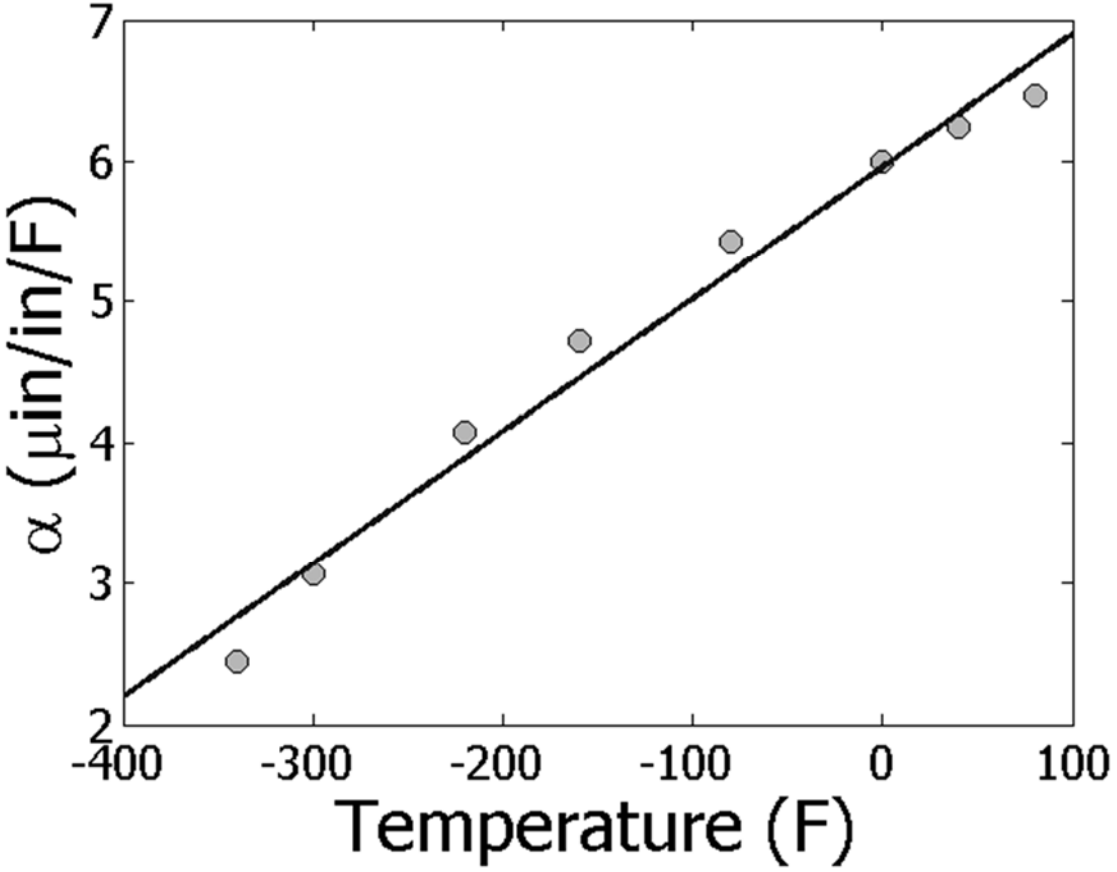



# Regression

Thermal expansion coefficient data for cast steel



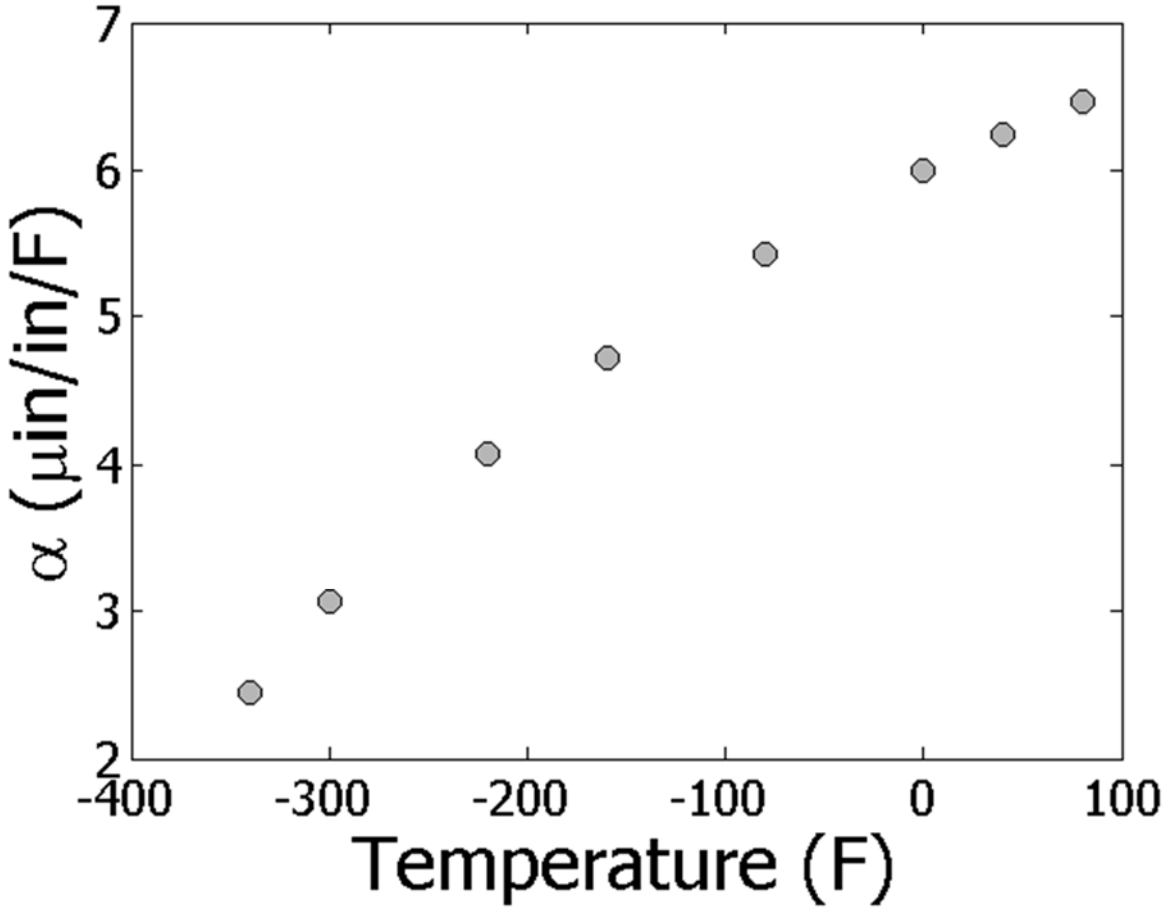
# Regression (cont)



# Integration

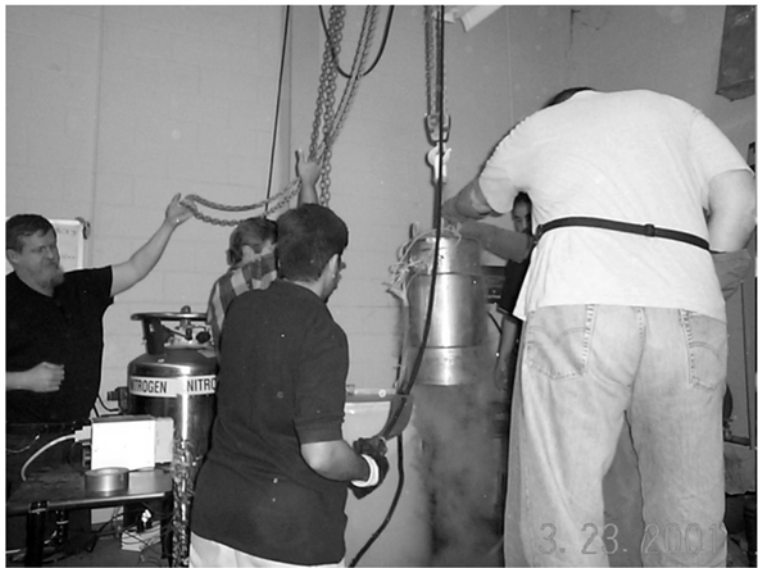
Finding the diametric contraction in a steel shaft when dipped in liquid nitrogen.

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



# Ordinary Differential Equations

How long does it take a trunnion to cool down?



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

# THE END

http://nm.MathForCollege.com