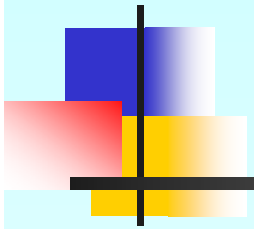
Introduction to Scientific Computing

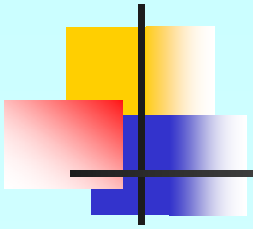


Major: All Engineering Majors

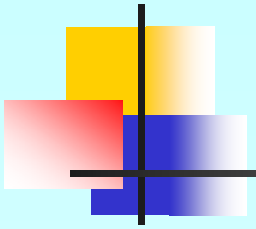
Authors: Autar Kaw, Luke Snyder

http://numericalmethods.eng.usf.edu

Numerical Methods for STEM undergraduates



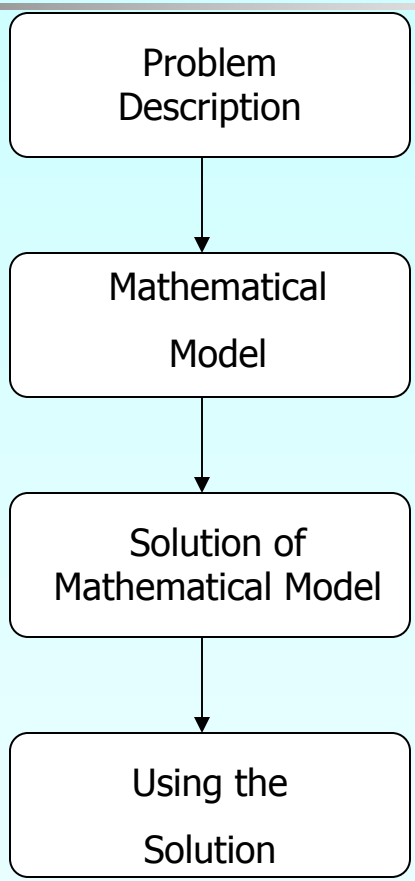
Introduction



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*

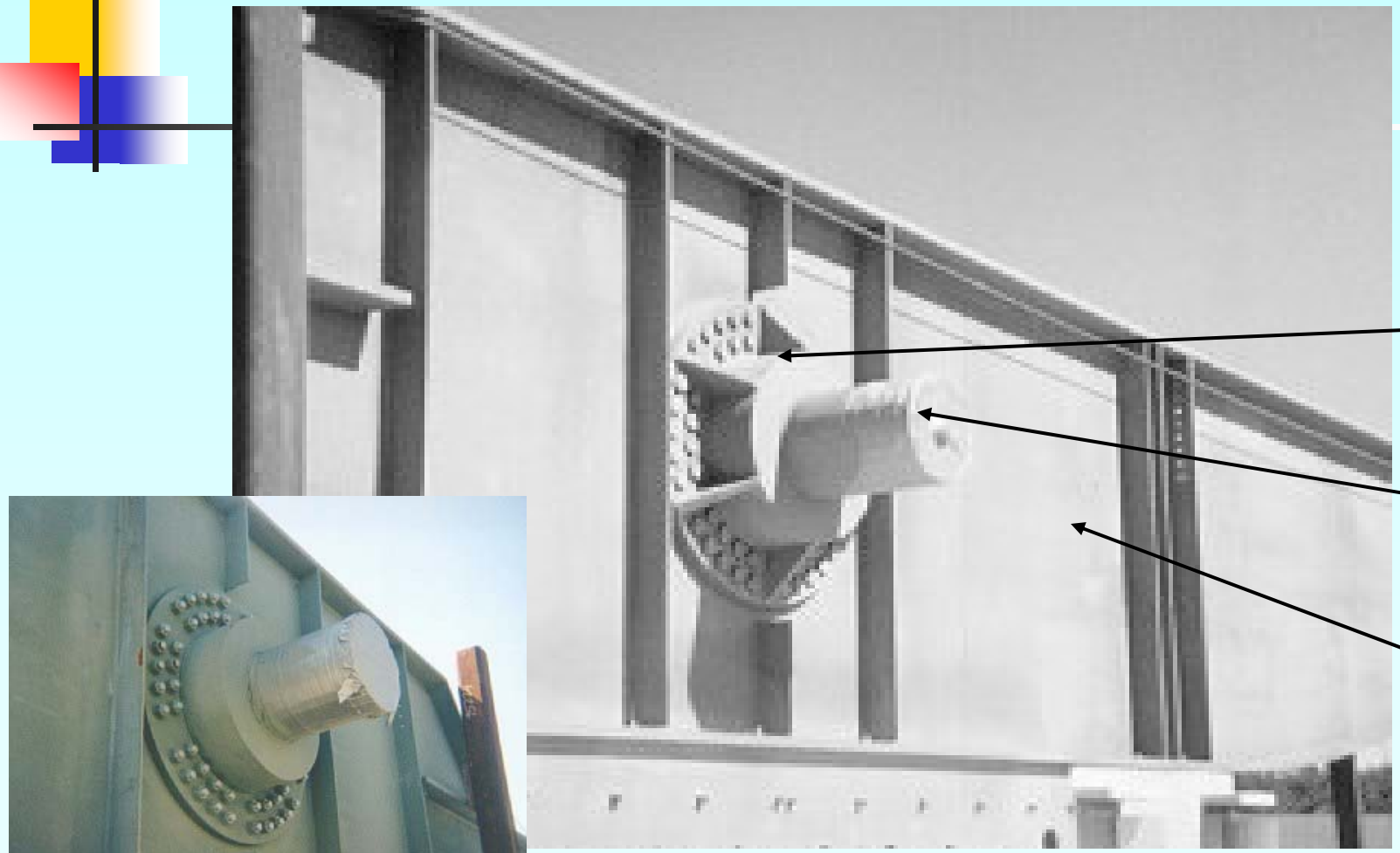
How do we solve an engineering problem?



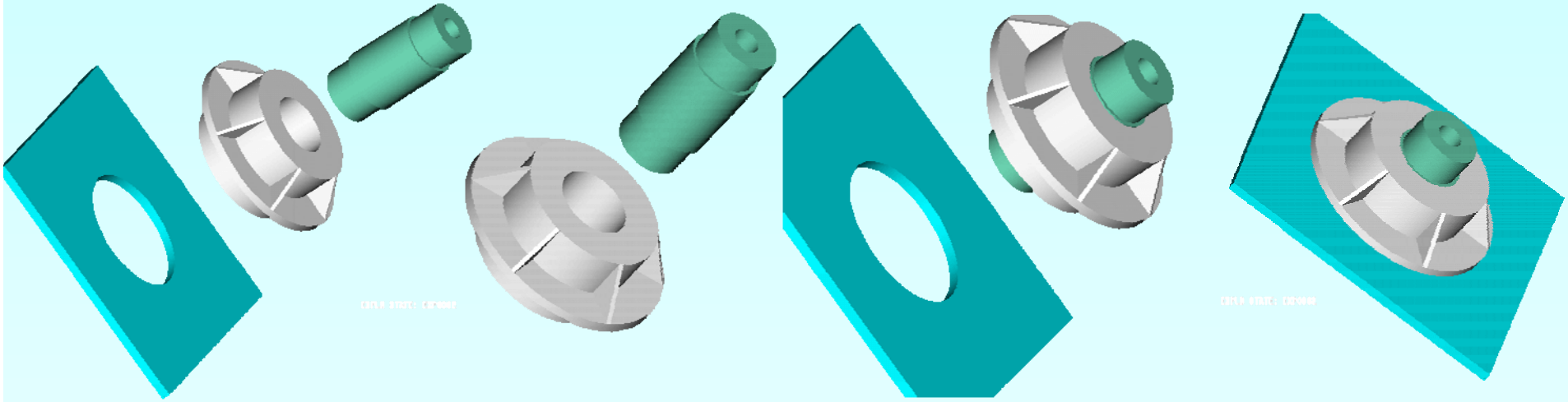
BRIDGE of LIONS (1927)

Bascule Bridge THG

Bascule Bridge THG



Trunnion-Hub-Girder Assembly Procedure



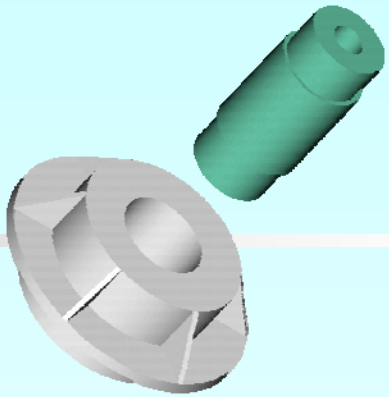
Step1. Trunnion immersed in dry-ice/alcohol

Step2. Trunnion warm-up in hub

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

Step4. Trunnion-Hub warm-up into girder

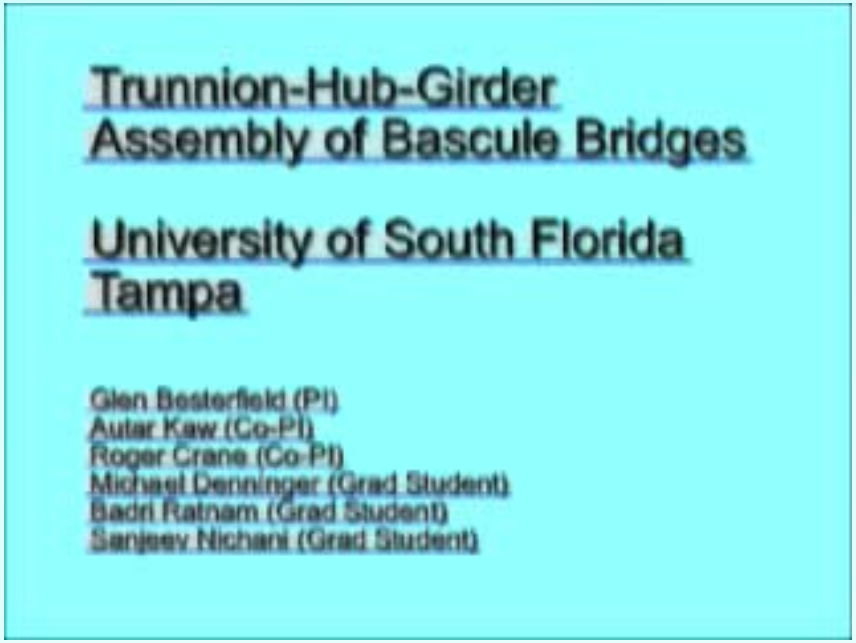
Problem



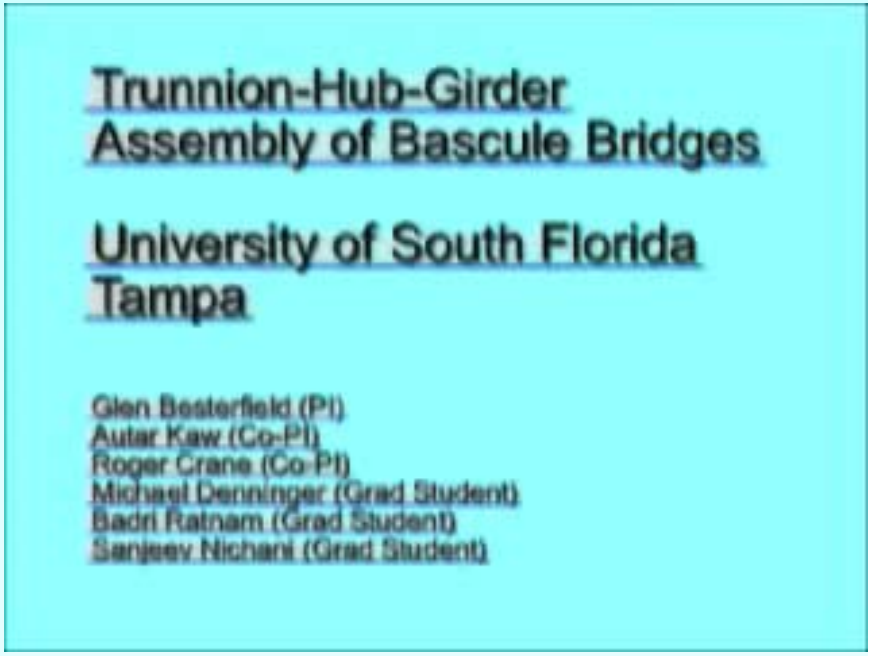
Trunnion Stuck in Hub

Venetian Causeway Bridge

Video of Assembly Process



Unplugged Version



VH1 Version

Consultant calculations

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

$D = 12.363"$

$\alpha = 6.47\times10^{-6} in/in/^{o} F$ at room temperature of 80^{o} F

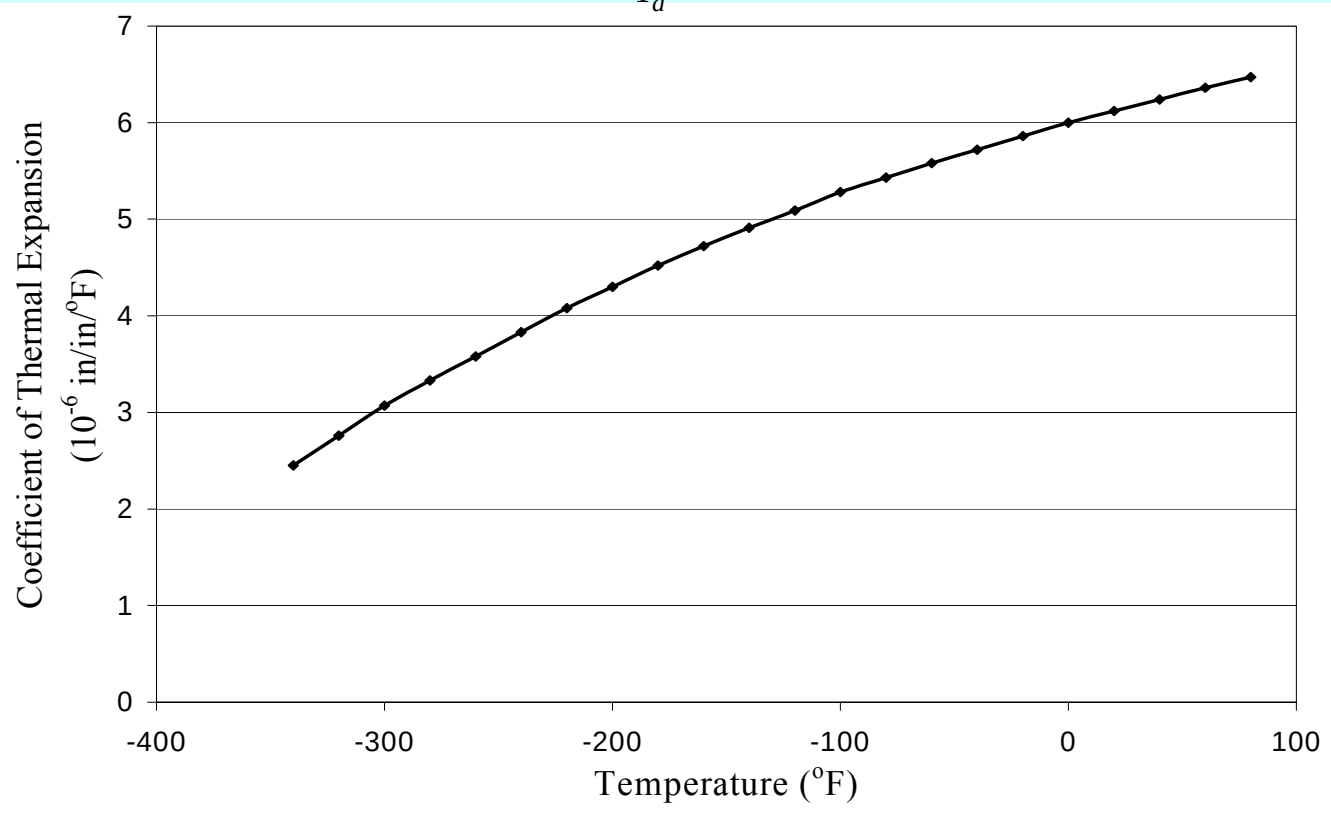
$\Delta T = -108 - 80 = -188^{o} F$

$\Delta D = (12.363)(6.47\times10^{-6})(-188) = -0.01504"$

Clearance needed was 0.015” or more

Thermal Expansion Coefficient Variation with Temperature

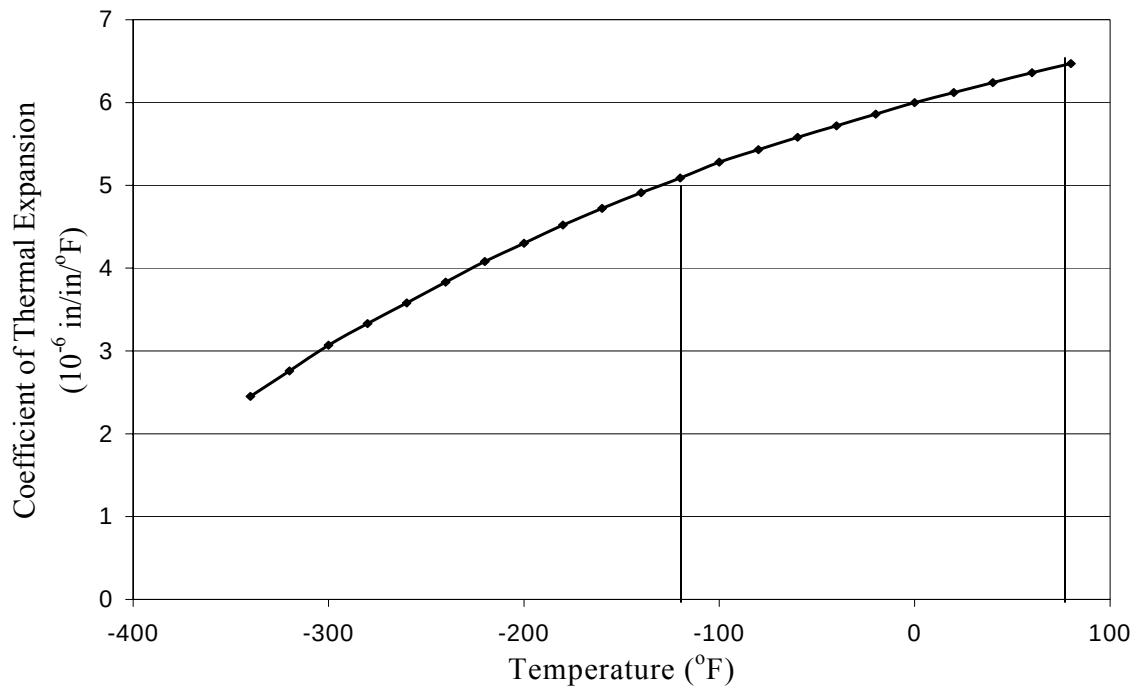
$$\Delta D = D\int_{T_a}^{T_c} \alpha(T)dT$$



Roughly estimate the contraction using trapezoidal rule

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

T_a=80°F; T_c=-108°F; D=12.363”



Estimating Contraction Accurately

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

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

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

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

ΔD =-0.0137"

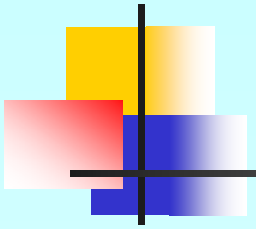
Revisiting steps to solve a problem

1) Problem Statement: Trunnion getting stuck into the hub.
2) Modeling: Developed the current model for diametric contraction of the trunnion,

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

3) Solution: We solved the model by using regression and integration.

4) Implementation: We solved existing problem by cooling the trunnion in liquid nitrogen.

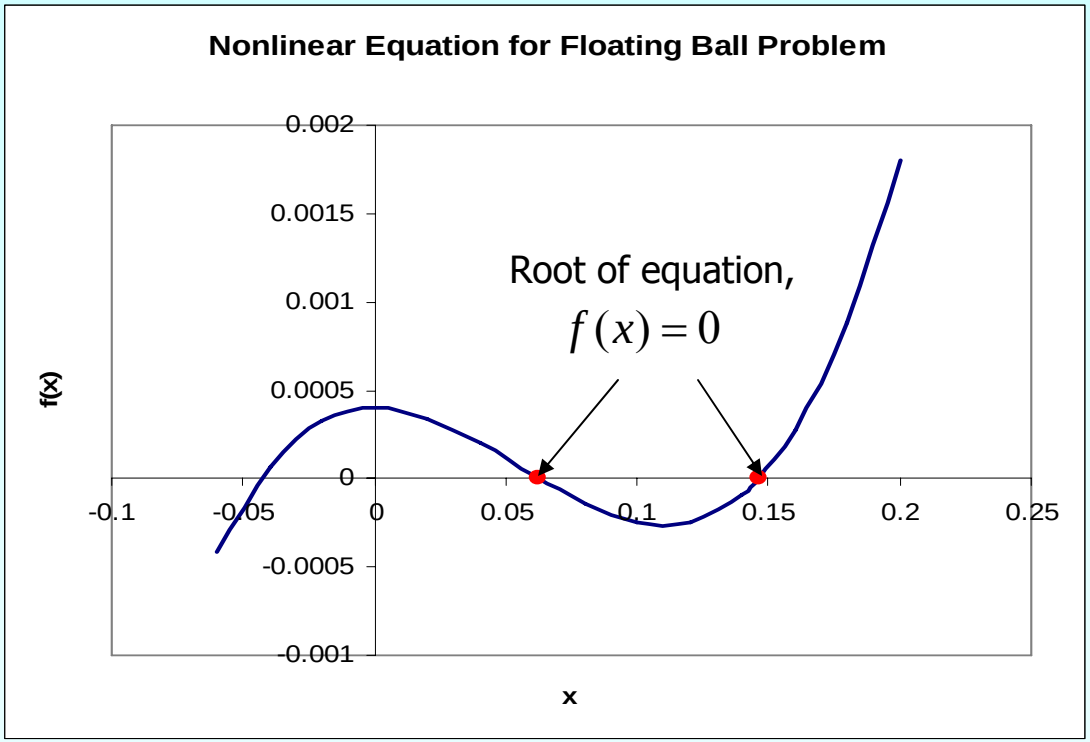


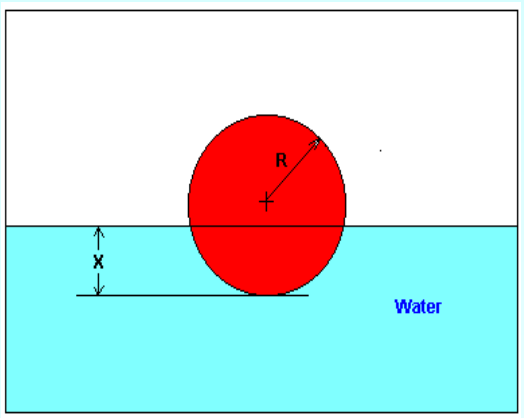
Mathematical Procedures

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

Nonlinear Equations

Floating Ball Problem

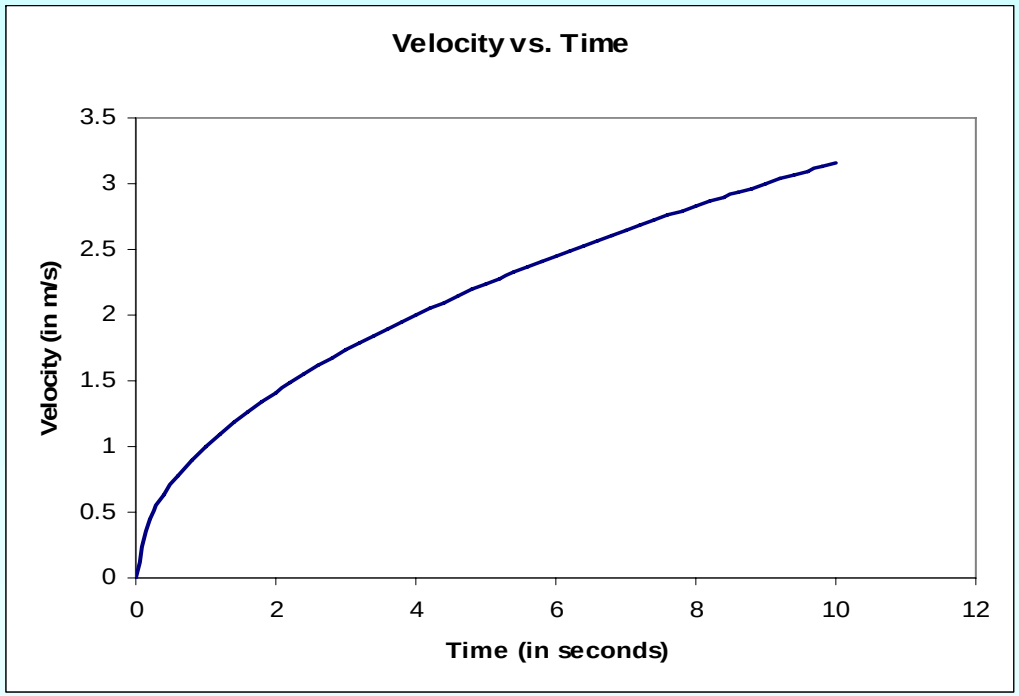




$$f(x) = x^3 - 0.165x^2 + 3.993\times10^{-4}$$

Differentiation

Velocity vs. time rocket problem



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

What is the acceleration at t=10 seconds?

Simultaneous Linear Equations

Find the velocity profile from

Time,t	Velocity,v
s	m/s
5	106.8
8	177.2
12	279.2

$$v(t) = at^2 + bt + c$$

$$5 \le t \le 12$$

Three simultaneous linear equations:

$$25a + 5b + c = 106.8$$

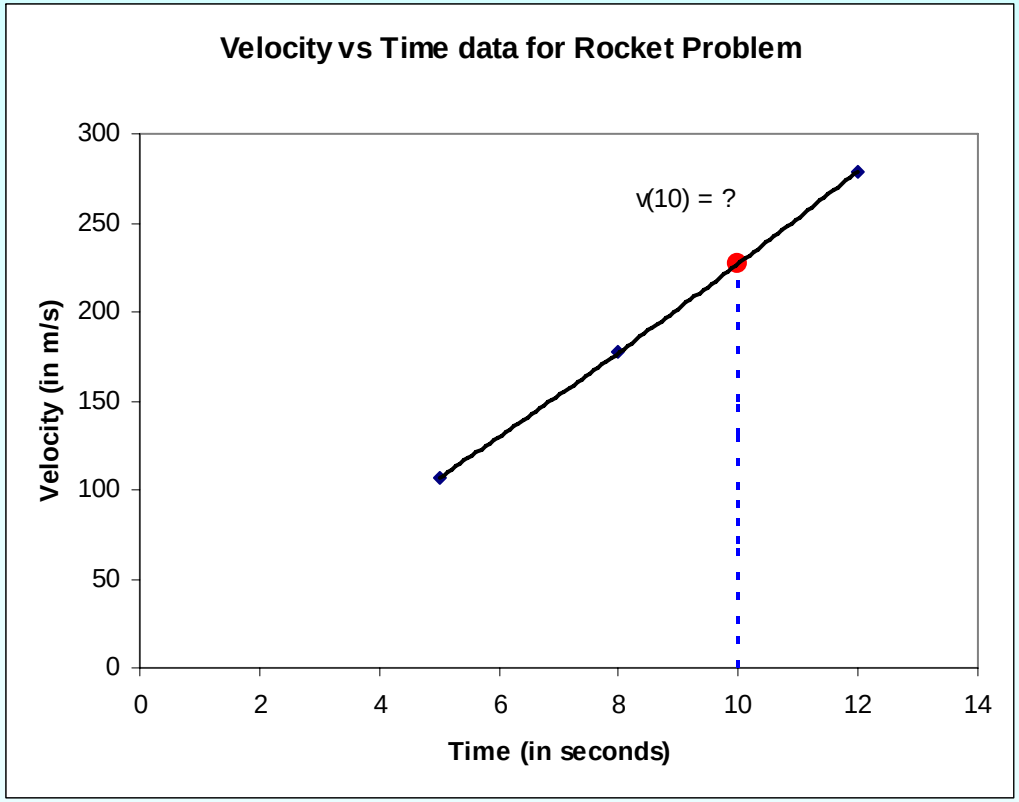
$$64a + 8b + c = 177.2$$

$$144a + 12b + c = 279.2$$

Interpolation

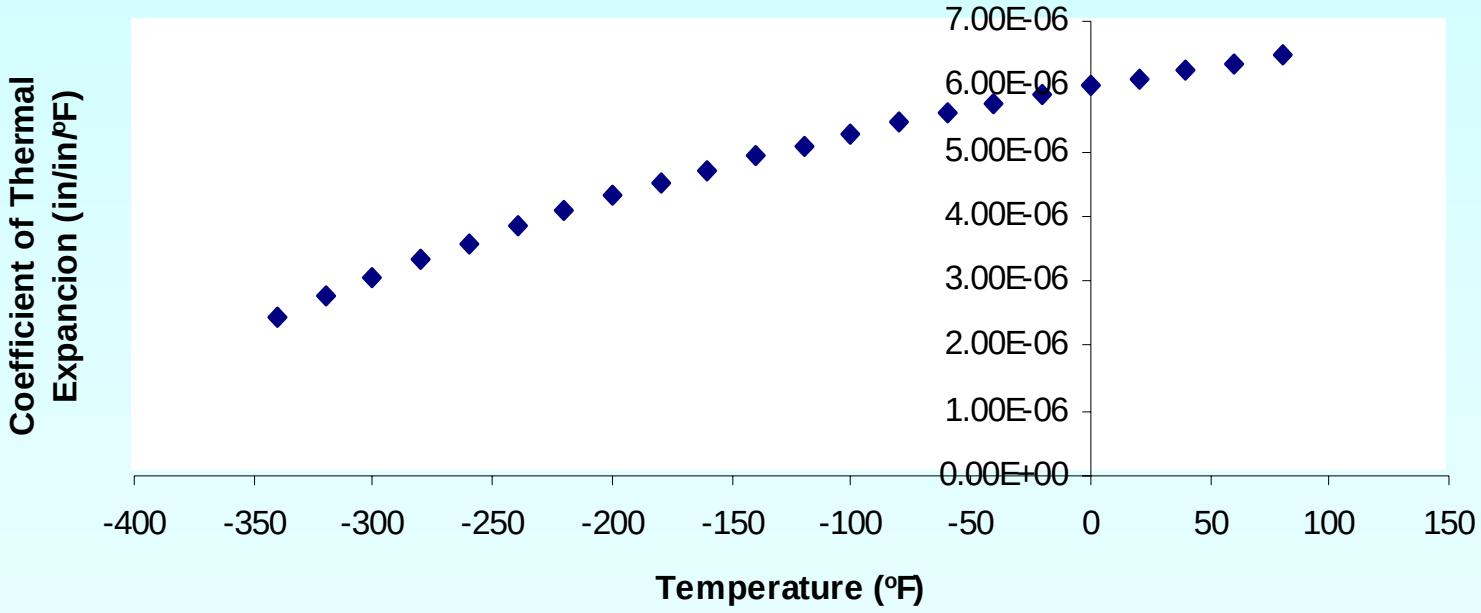
What is the velocity of the rocket at t=10 seconds?

Time,t	Velocity,v
s	m/s
5	106.8
8	177.2
12	279.2



Regression

Thermal expansion coefficient data for cast steel:

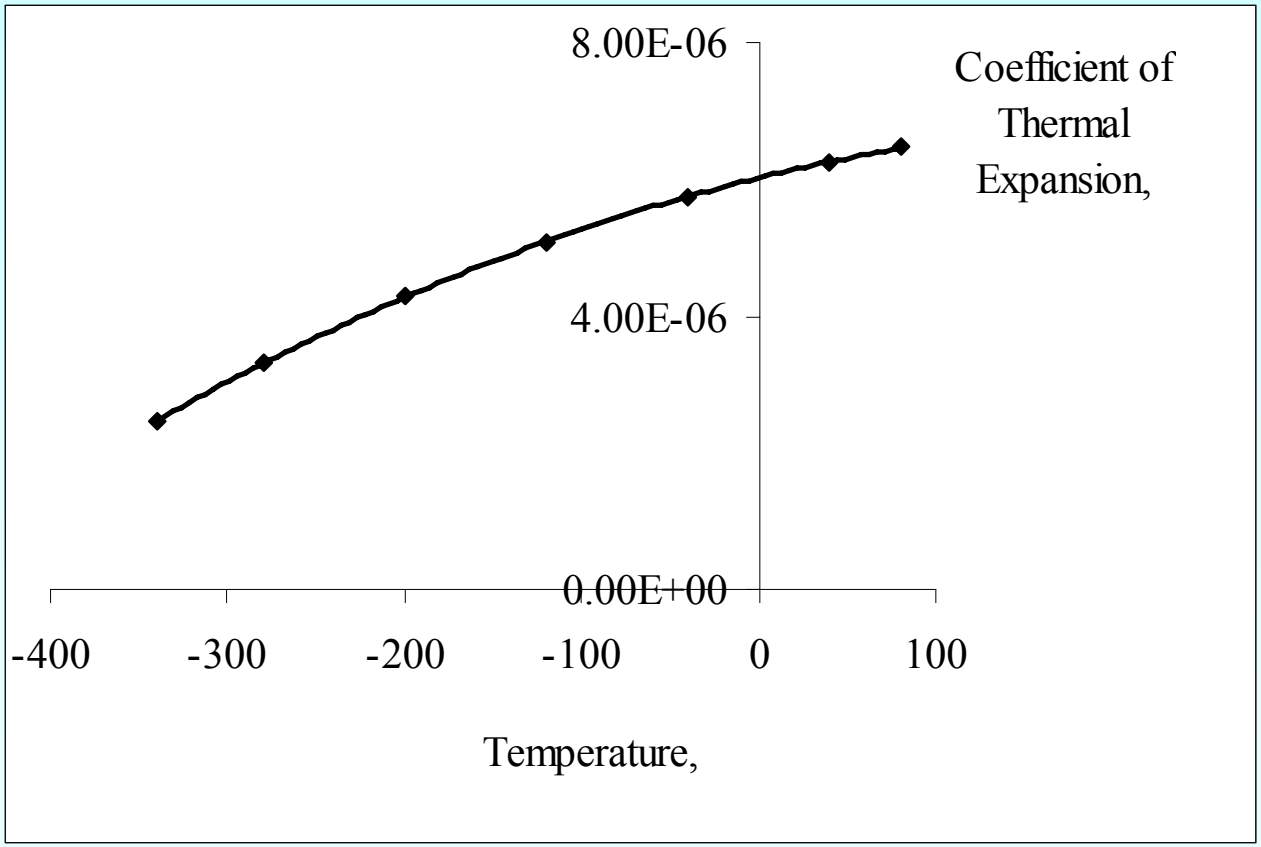


Regression is used to curve fit the data.

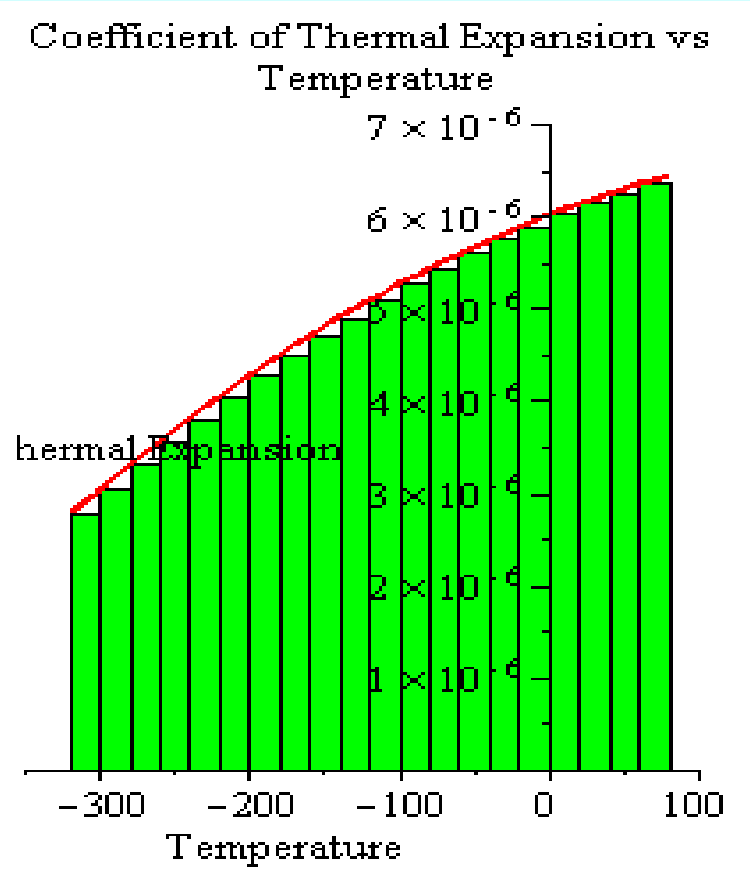
Regression (cont)

$$\alpha = a_0 + a_1 T + a_2 T^2$$

$$= 6.0217 \times 10^{-6} + 6.2782 \times 10^{-9} \mathrm{T} - 1.2218 \times 10^{-11} \mathrm{T}^2$$



Integration



Finding the contraction in a trunnion

$$\alpha = a_0 + a_1 T + a_2 T^2$$
$$= 6.0217 \times 10^{-6} + 6.2782 \times 10^{-9} \mathrm{T} - 1.2218 \times 10^{-11} \mathrm{T}^2$$

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

Ordinary Differential Equations

How long does it take the trunnion to cool down?

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