The slide features a background image of a bright, cloudy sky. In the upper left, there is a small blue circular icon with a white dot inside. The title "EML304I" is centered in a large, dark blue font, with "Computational Methods" centered below it in a slightly smaller, dark blue font. Below the title, the URL "http://nm.MathForCollege.com" is displayed in green, underlined text. Underneath the URL, the text "Transforming Numerical Methods Education for STEM Undergraduates" is written in a smaller, dark blue font. At the bottom right, the date "8/23/2020" and the URL "http://nm.MathForCollege.com" are shown in a small, dark blue font, followed by the number "1" in a small, dark blue font.

EML304I

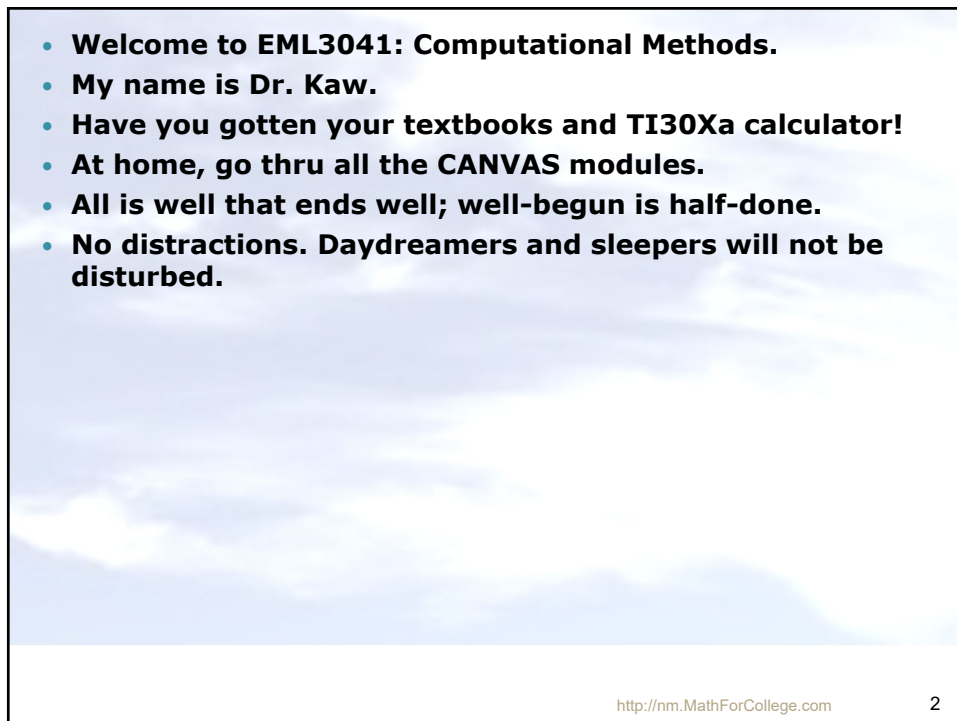
Computational Methods

<http://nm.MathForCollege.com>

Transforming Numerical Methods Education for STEM Undergraduates

8/23/2020 <http://nm.MathForCollege.com> 1

1

The slide features a background image of a bright, cloudy sky. A list of six bullet points is displayed in the upper left quadrant. The text "http://nm.MathForCollege.com" is shown at the bottom right in a small, dark blue font, followed by the number "2" in a small, dark blue font.

- **Welcome to EML3041: Computational Methods.**
- **My name is Dr. Kaw.**
- **Have you gotten your textbooks and TI30Xa calculator!**
- **At home, go thru all the CANVAS modules.**
- **All is well that ends well; well-begun is half-done.**
- **No distractions. Daydreamers and sleepers will not be disturbed.**

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Why use Numerical Methods?

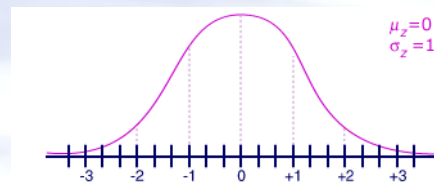


3

Why use Numerical Methods?

- To solve problems that cannot be solved exactly

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



4

Why use Numerical Methods?

- To solve problems that are intractable to solve exactly!



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Steps in Solving an Engineering Problem

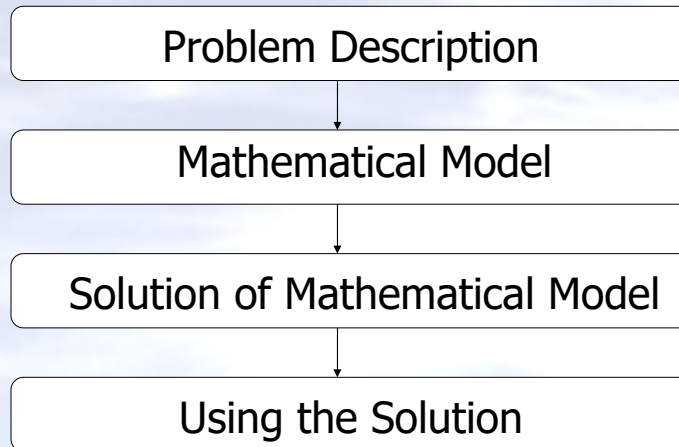
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How do we solve an engineering problem?

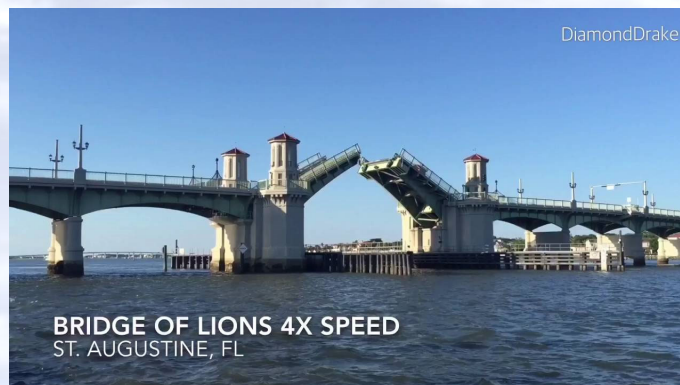


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Example of Solving an Engineering Problem



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Bascule Bridge THG

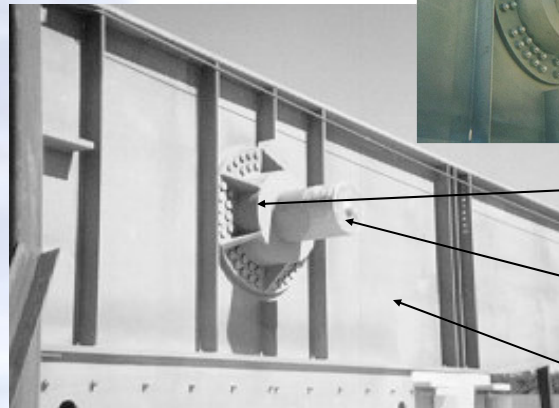


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Bascule Bridge THG



Hub

Trunnion

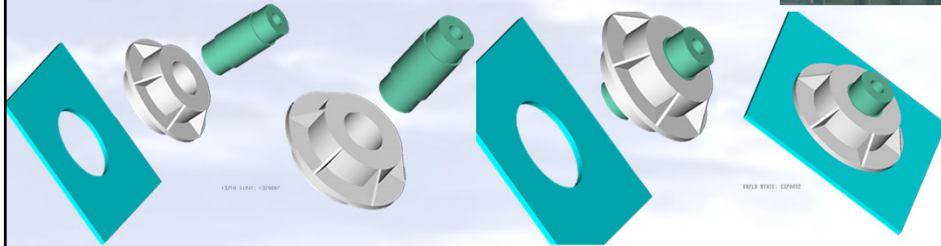
Girder

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Trunnion-Hub-Girder Assembly Procedure



Simulation

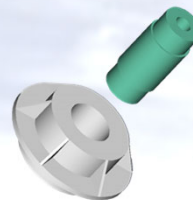
- Step1.** Trunnion immersed in dry-ice/alcohol
- Step2.** Trunnion warm-up in hub
- Step3.** Trunnion-Hub immersed in dry-ice/alcohol
- Step4.** Trunnion-Hub warm-up into girder

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Problem



After Cooling, the Trunnion Got Stuck in Hub

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Why did it get stuck?

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

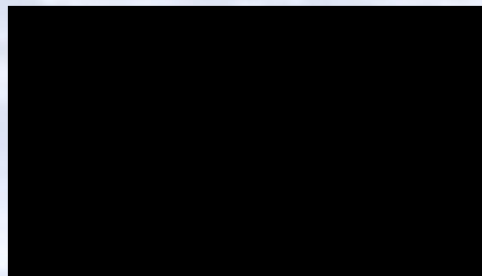


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Video of Assembly Process



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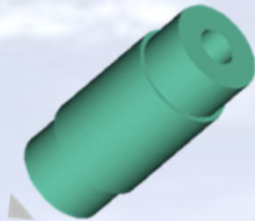
Consultant calculations

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

$$D = 12.363"$$

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

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



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

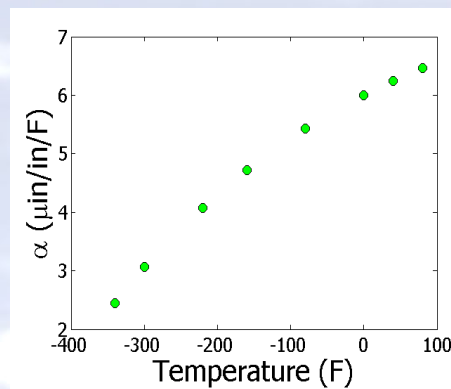
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Is the formula used correct?

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



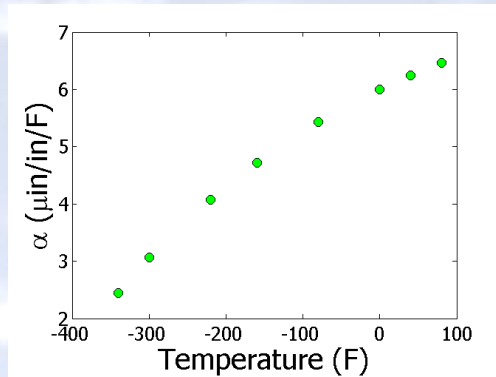
T(°F)	α (μin/in/°F)
-340	2.45
-300	3.07
-220	4.08
-160	4.72
-80	5.43
0	6.00
40	6.24
80	6.47

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The Correct Model Would Account for Varying Thermal Expansion Coefficient



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

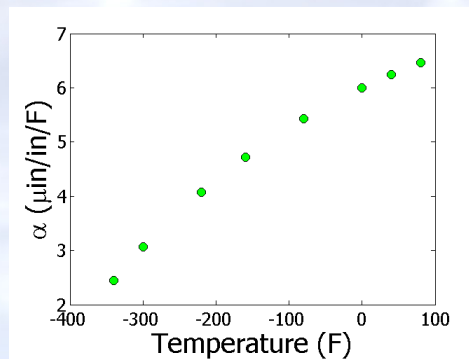
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Can You Roughly Estimate the Contraction?

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



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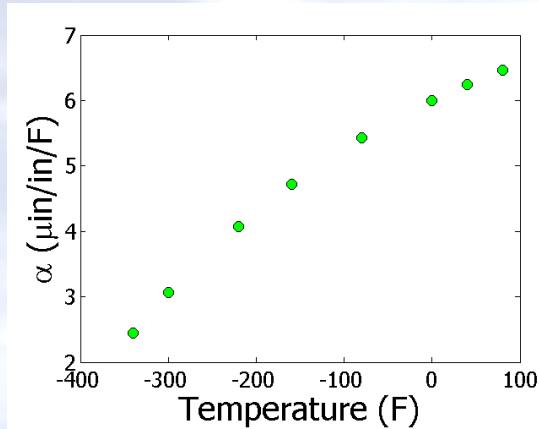
Can You Find a Better Estimate for the Contraction?

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

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

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

$$D = 12.363''$$



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Estimating Contraction Accurately

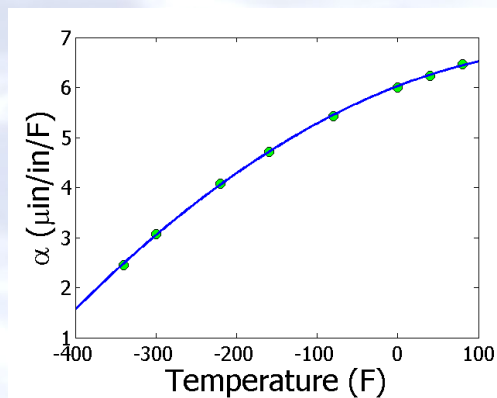
Change in diameter (ΔD) by cooling it in dry ice/alcohol is given by

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

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

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

$$D = 12.363''$$



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

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

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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°F as opposed to the dry-ice/alcohol temperature of -108°F .

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

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Revisiting steps to solve a problem

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

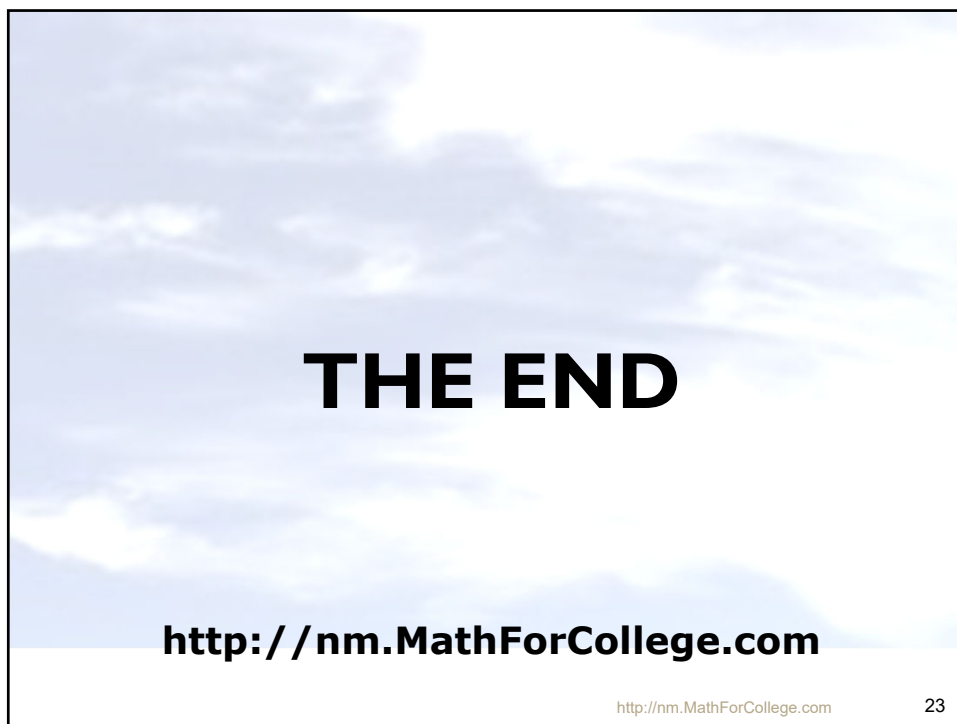
$$\Delta D = D \int_{T_a}^{T_c} \alpha(T) dT$$

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

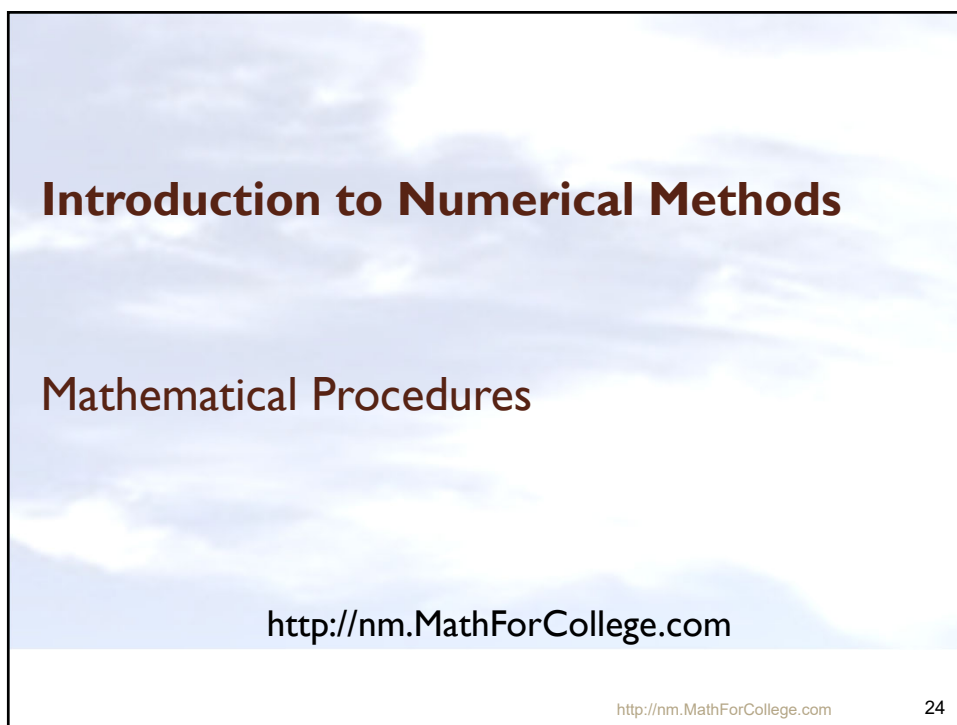
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Mathematical Procedures

- 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

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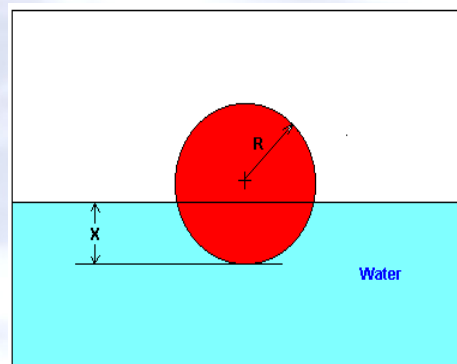
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Nonlinear Equations

How much of the floating ball is under water?

Diameter=0.11m
Specific Gravity=0.6



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

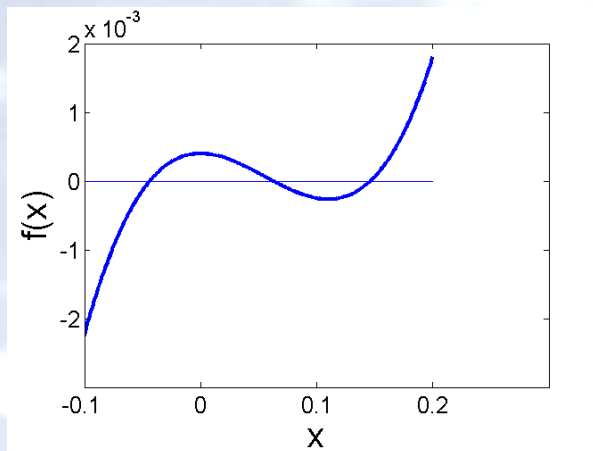
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Nonlinear Equations

How much of the floating ball is under the water?



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

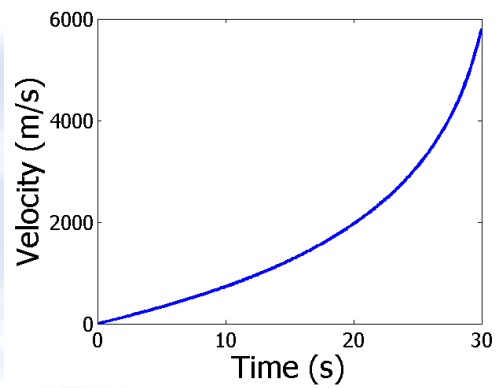
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Differentiation

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



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

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

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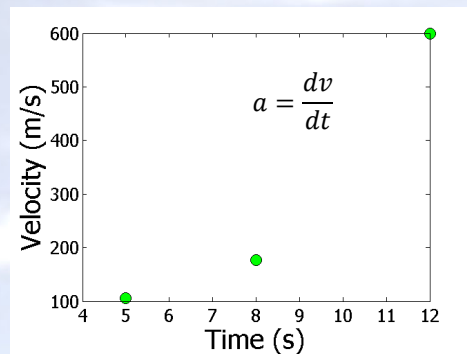
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Differentiation

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

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



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Simultaneous Linear Equations

Find the velocity profile, given

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



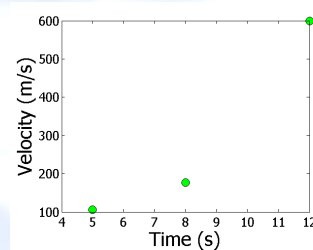
$$v(t) = at^2 + bt + c, \quad 5 \leq t \leq 12$$

Three simultaneous linear equations

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

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

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



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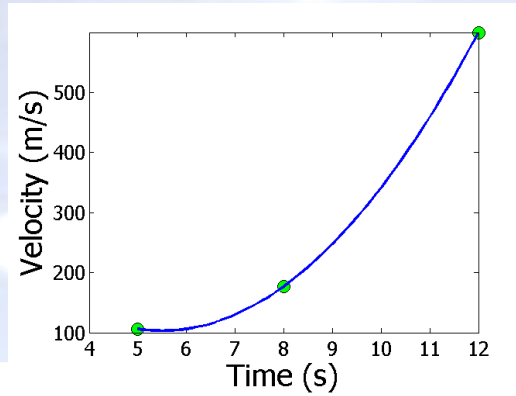
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Interpolation

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

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



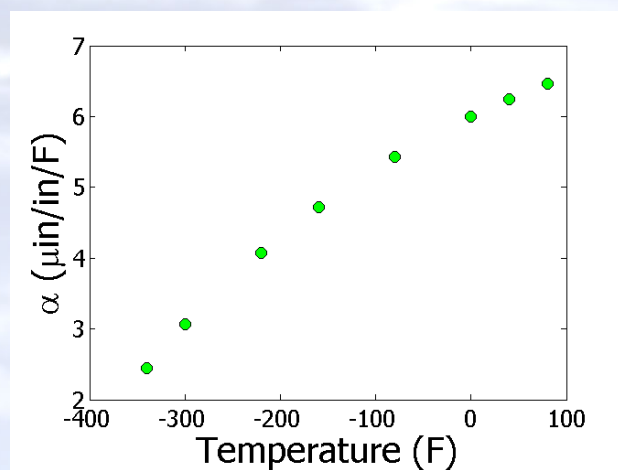
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Regression

Thermal expansion coefficient data for cast steel

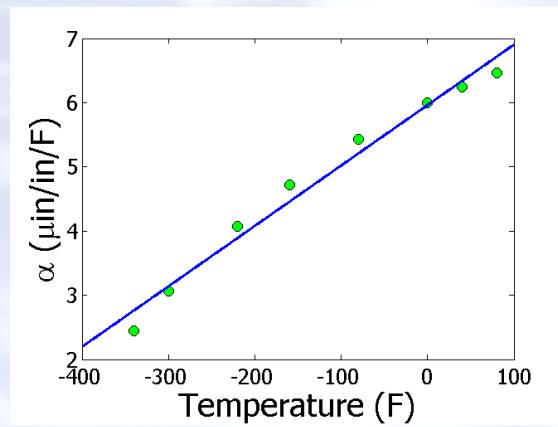


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Regression (cont)



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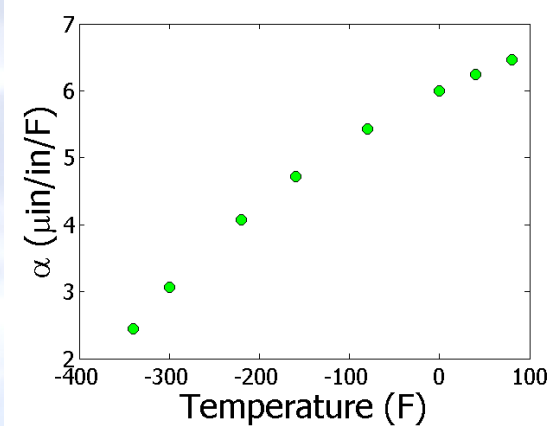
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Integration

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

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



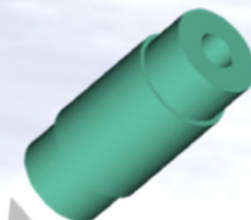
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Ordinary Differential Equations

How long does it take a trunnion to cool down?



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

$$\theta(0) = \theta_{room}$$

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