Computational Methods

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Transforming Numerical Methods Education for STEM Undergraduates

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- Welcome to EML3041: Computational Methods.
- My name is Dr. Kaw.
- **Introduce yourself to the person on your left and right. Say one thing (nothing personal) about yourself to them.**
- All is well that ends well; well-begun is half-done.
- Cell phones, laptops or other distractions are discouraged other than for allowed use. Tablet when laid flat and writing with a pen is OK.
- Daydreamers and sleepers will not be disturbed.

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Why use Numerical Methods?

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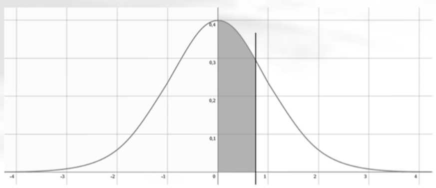
Why use Numerical Methods?

- To solve problems that cannot be solved exactly

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



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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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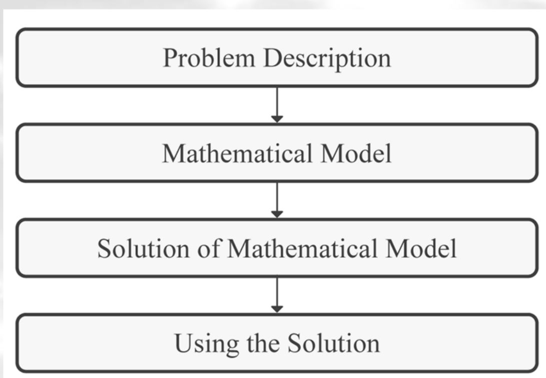
How do we solve an engineering problem?



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PROBLEM DESCRIPTION

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Example of Solving an Engineering Problem

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Bascule Bridge THG

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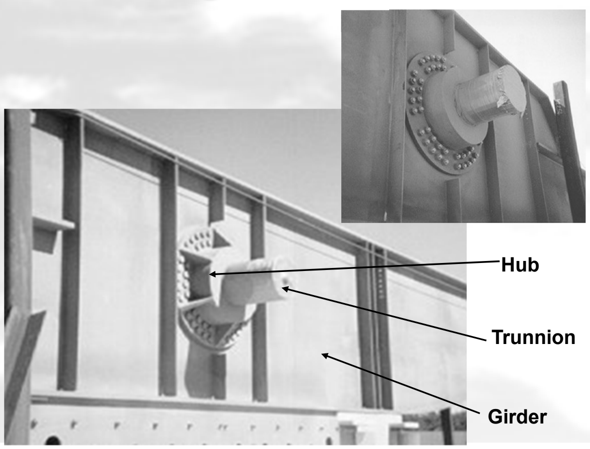
Bascule Bridge THG



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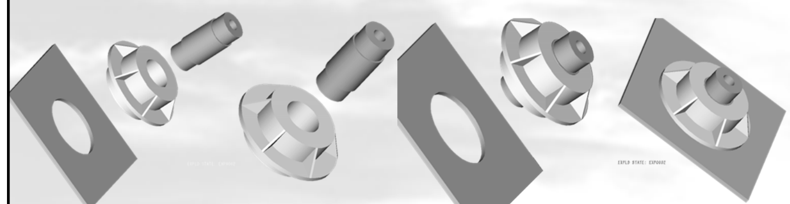
Trunnion-Hub-Girder Assembly Procedure



Step1. Trunnion immersed in dry-ice/alcohol
Step2. Trunnion shrink fit and warm up
Step3. Trunnion-hub immersed in dry-ice/alcohol
Step4. Trunnion-hub shrink fit and warm-up

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Problem

After cooling the trunnion, 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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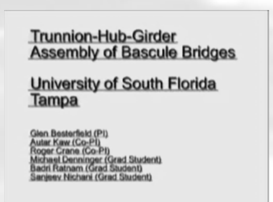
Video of Assembly Process



http://www.eng.usf.edu/~kaw/download/today/Assembly_procedure2_256.wmv

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MATHEMATICAL MODELING

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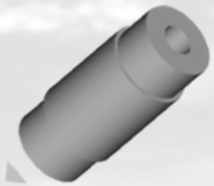
Consultant Calculations



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

$$D = 12.363''$$

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

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

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

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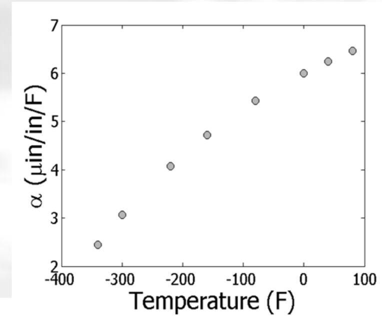
Is the $\Delta D = D\alpha\Delta T$ formula correct?

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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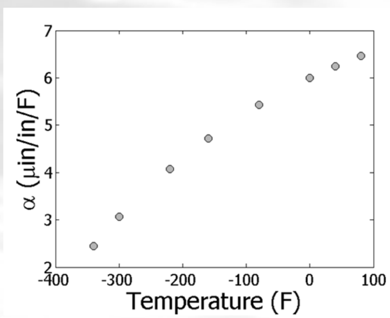
The correct model would account for varying thermal expansion coefficient

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



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SOLUTION OF MATHEMATICAL MODEL

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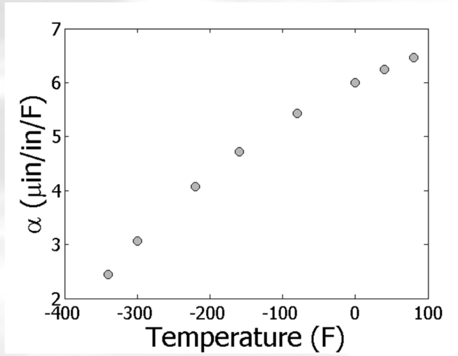
Can you roughly estimate the contraction?

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

$T_a = 80°\text{F}$
$T_c = -108°\text{F}$
$D = 12.363"$



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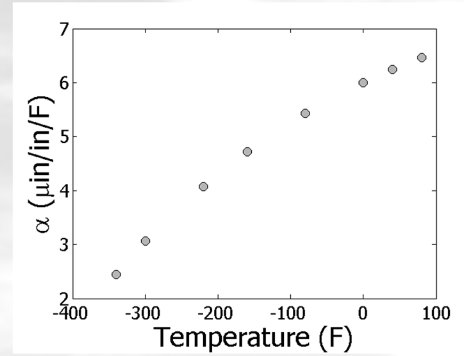
Can you find a better estimate for the contraction?

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

$T_a = 80°\text{F}$
$T_c = -108°\text{F}$
$D = 12.363"$



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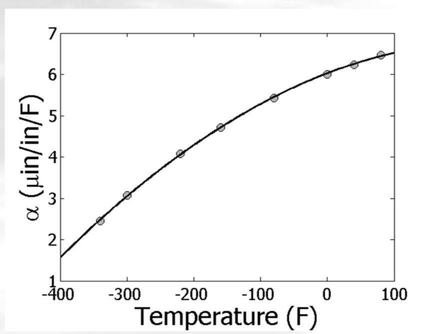
Can you estimate the contraction more accurately?

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

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

$T_a = 80°\text{F}$
$T_c = -108°\text{F}$
$D = 12.363"$

$\Delta D = -0.0137"$



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USING THE SOLUTION

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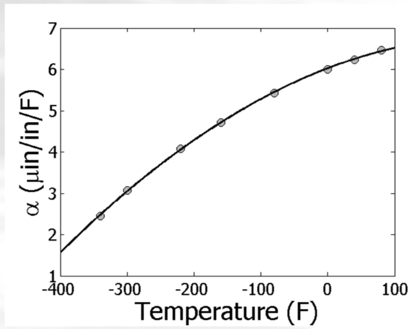
So, what is the solution to the problem?

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

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

$T_a = 80°\text{F}$
$T_c = -321°\text{F}$
$D = 12.363"$

$\Delta D = -0.0244"$



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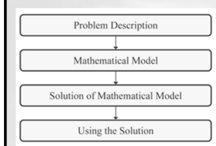
Revisiting steps to solve a problem



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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How the course works

Before Tuesday class
Have all the assigned modules including post-class quizzes and problem sets. done. Check syllabus link in CANVAS

During class
Attend lectures, answer concept questions via PollEverywhere, free-response questions.

After every class
Finish assigned modules including textbook pages, post-class quizzes, multiple-choice quiz solutions, and problem sets as per CANVAS announcement of the week.

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How Standard Based Grading Works?

Unit Test
Take unit test on assigned chapters

Retake Unit Test
Take retake of unit test on any chapter(s). You can earn PARTIAL credit if you do better (max of 90%)

Final Exam
Final exam is mandatory for all students but the questions on it will count as a retake also. You can earn PARTIAL credit if you do better (max of 90%)

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Some examples of standards-based grading

Example 1: You take Unit Test 1 and you will get a score for Chapter1, Chapter 2 and Chapter 3. You score a 25/40 in Chapter 1 questions. In the retake, you make 20/40 in Chapter 1 questions, and in the final exam, you make 15/40 in Chapter 1 questions. Your score for Chapter 1 Unit Test will stay at 25 out of 40.

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Some examples of standards-based grading

Example 2: You take Unit Test 1 and you will get a score for Chapter1, Chapter 2 and Chapter 3. You score a 25/40 in Chapter 1 questions. In the retake, you make 32/40 in Chapter 1 questions, and in the final exam, you make 15/40 in Chapter 1 questions. Your score for Chapter 1 will be 25+(32-25)/2=28.5 out of 40. Since the final exam score is lower than 28.5, your Chapter 1 Unit Test will stay at 28.5 out of 40 score.

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Some examples of standards-based grading

Example 3: You take Unit Test 1 and you will get a score for Chapter1, Chapter 2 and Chapter 3. You score a 25/40 in Chapter 1 questions. In the retake, you make 32/40 in Chapter 1 questions, and in the final exam, you make 38/40 in Chapter 1 questions. Your score for Chapter 1 after the retake will be 25+(32-25)/2=28.5 out of 40 as shown in Example 2. After the final exam, Chapter 1 Unit Test score will be 28.5+(38-28.5)/2=33.25 out of 40.

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To Do List

- Go through the Module 00.XX – syllabus.
- Take attendance quiz on CANVAS before Thursday 8am, and start on it today as it will take you sometime to do it.
- Finish Module 01.01 before coming to class.
- Have you gotten your TI30Xa calculator?
- Download MATLAB and Adobe Acrobat DC today for free.
- Bring charged laptop with MATLAB on Friday.
- Turn on your notifications in CANVAS

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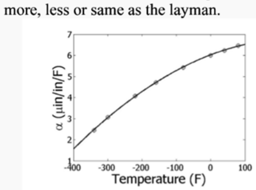
Steel Cylindrical Shaft

A steel cylindrical shaft at room temperature is immersed in a dry-ice/alcohol bath. A layman estimates the change in the shaft diameter by using

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

The value of the thermal expansion coefficient he uses is that at $-108°$F. Seeing the graph below, would the magnitude of contraction you would calculate as a USF educated engineer be more, less or same as the layman.



Less

More

Same

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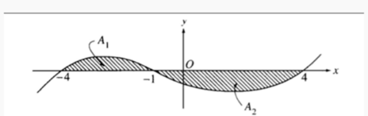
Given the $f(x)$ vs x curve, and the magnitude of the areas A_1 and A_2 as shown, the value of $\int_{-4}^{4} f(x)dx$ is



$A_2 - A_1$

$A_1 - A_2$

$A_1 + A_2$

$-A_1 - A_2$

Cannot be determined

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Arrange the four steps of solving an engineering problem by moving the four blocks in the correct order.

Describe the problem

Develop a mathematical model

Solve the mathematical problem

Implement a solution

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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

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Nonlinear Equations

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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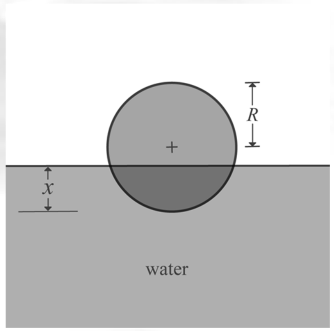
Nonlinear Equations

How much of the floating ball is under water?

Radius=0.055 m

Specific Gravity=0.6

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



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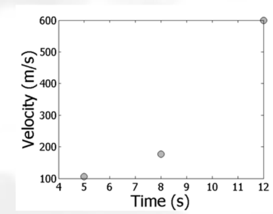
Simultaneous Linear Equations

Find the velocity profile, given

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

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



Three simultaneous linear equations

$$a(5^2) + b(5) + c = 106$$
$$a(8^2) + b(8) + c = 177$$
$$a(12^2) + b(12) + c = 600$$

Source: Photo by NASA

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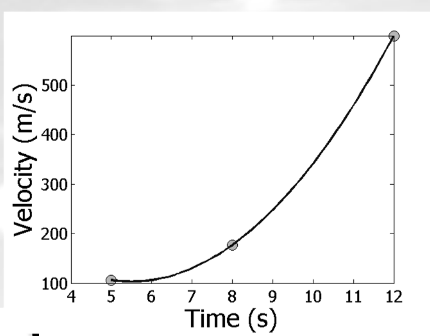
Interpolation

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

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



Source: Photo by NASA

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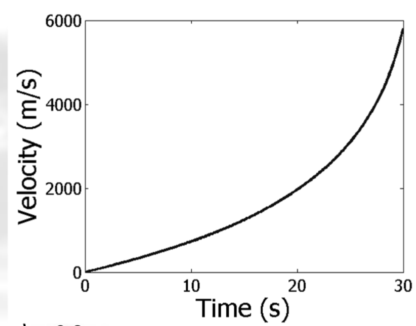
Differentiation

What is the acceleration at t=7 seconds?



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

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

Source: Photo by NASA

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Differentiation

What is the acceleration at t=7 seconds?

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

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

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

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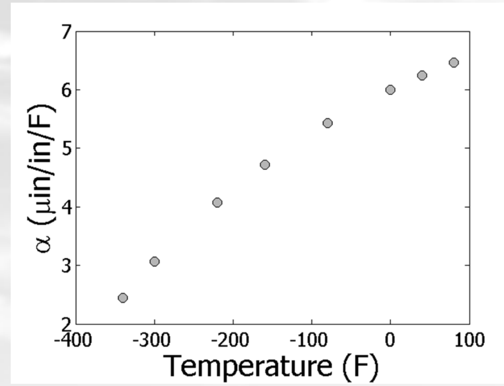
Regression

Thermal expansion coefficient data for cast steel



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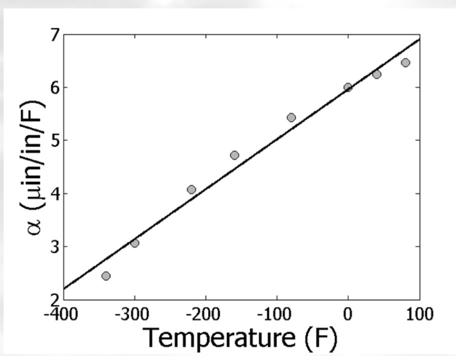
Regression – Linear



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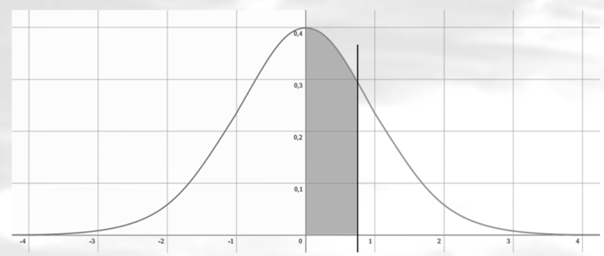
Integration

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-t^2/2}\, dt$$



Source: Wikipedia.org https://upload.wikimedia.org/wikipedia/commons/thumb/f/f9/Z_cumulative_from_mean.svg/1704px-Z_cumulative_from_mean.svg.png

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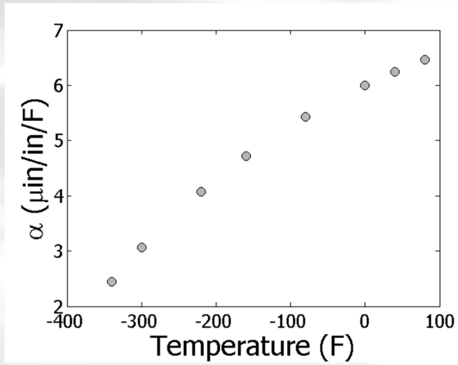
Integration

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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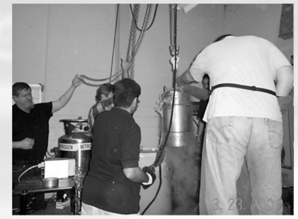
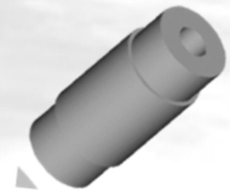
Ordinary Differential Equations

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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THE END

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