

# Adaptive Learning Platform for Engineering Dynamics

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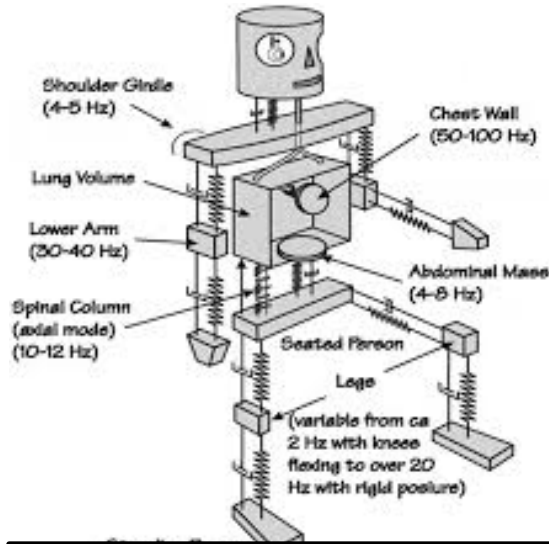
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Engineering Dynamics is a core junior-level course that covers the fundamentals of modeling engineering systems through differential equations. In this presentation, we outline how we used the Realizit Adaptive Learning platform at UNC Charlotte to develop an adaptive Approach and how we leveraged data-driven insights to support student success in Mechanical Engineering's System Dynamics curriculum.

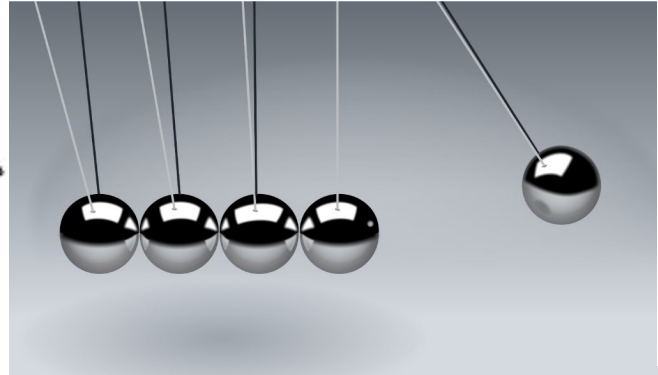
## Organization

- Key differences and benefits of AL
- How the adaptive approach was designed for Dynamics 2
- Tracking student progress and providing targeted support
- Conclusions and next steps

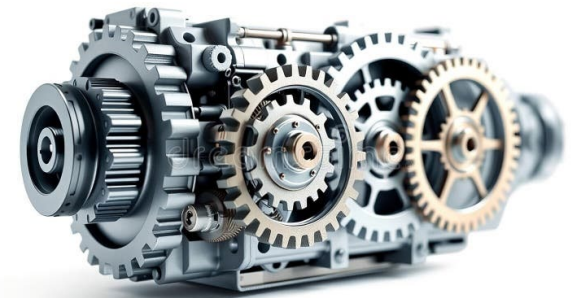
Engineering Dynamics is a core junior level course in engineering curricula that teaches the fundamentals of dynamic modeling of engineering systems with differential equations.



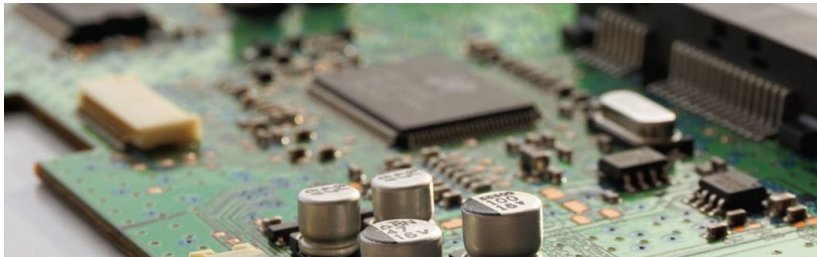
Rectilinear Motion Systems



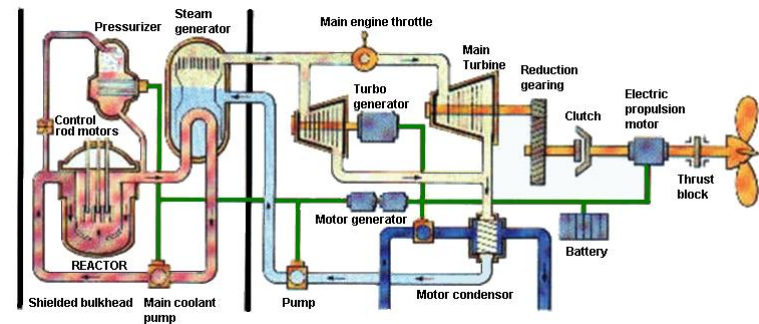
Rotational Motion System



Systems with Transmission Elements



Electrical Systems

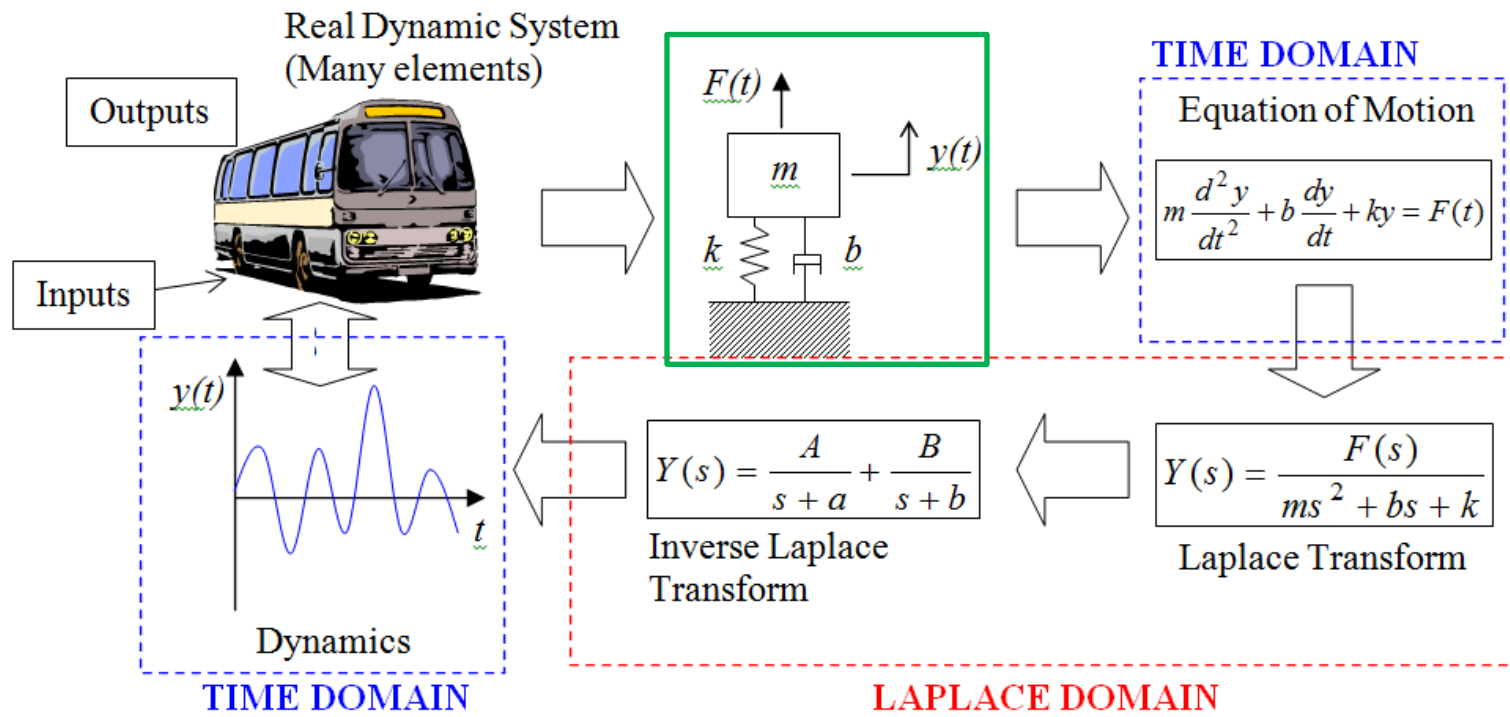


Thermal Systems



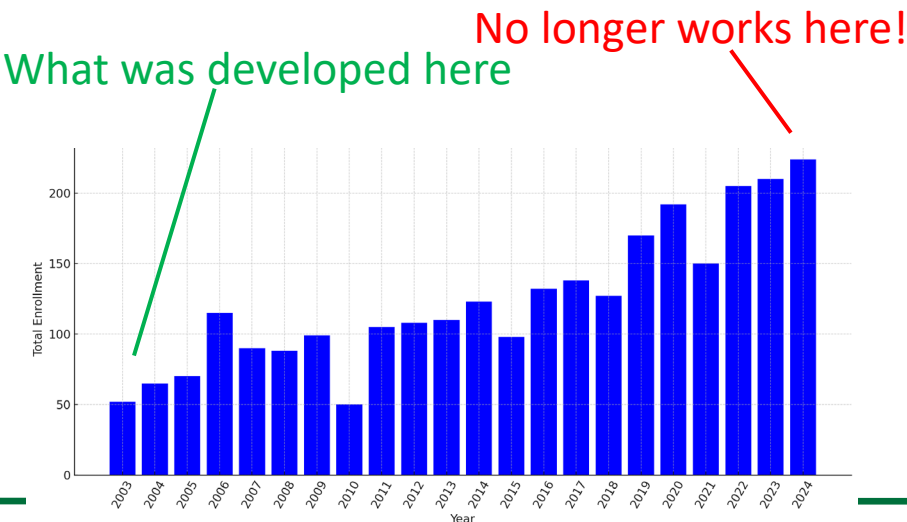
# Course Objectives

1. Understanding how physical systems translate into mathematical models
2. Applying differential equations, Laplace transforms, and transfer functions to describe the behavior of the system
3. Use MATLAB to simulate, analyze, and visualize system dynamics



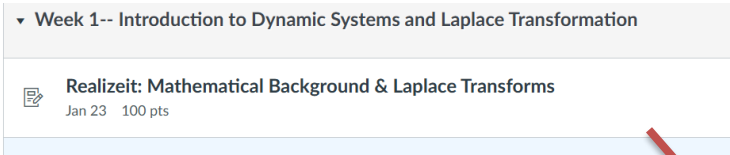
# Why Adopt Adaptive Learning for a course Like Dynamics 2

| Key Aspects                           | Traditional Approach                                                                  | Adaptive Learning Approach (Realizeit)                                                    |
|---------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Complex & Math-Intensive Content      | Limited repetitive exercises;                                                         | Near-infinite practice via randomized problems or parameters                              |
| Large, Diverse Classrooms             | One-size-fits-all lectures<br>Varied math backgrounds ignored.                        | Personalized pacing<br>Students advance based on mastery.                                 |
| Feedback & Grading                    | Slow manual grading;<br>misunderstandings linger too long.                            | Instant feedback on each question<br>Suggest what topics might need additional review     |
| Student Support & Intervention\$ fees | End-of-term evaluations<br>minimal data on individual progress.<br>\$100-ish textbook | Ongoing performance tracking<br>Timely instructor interventions.<br>\$35 registration fee |



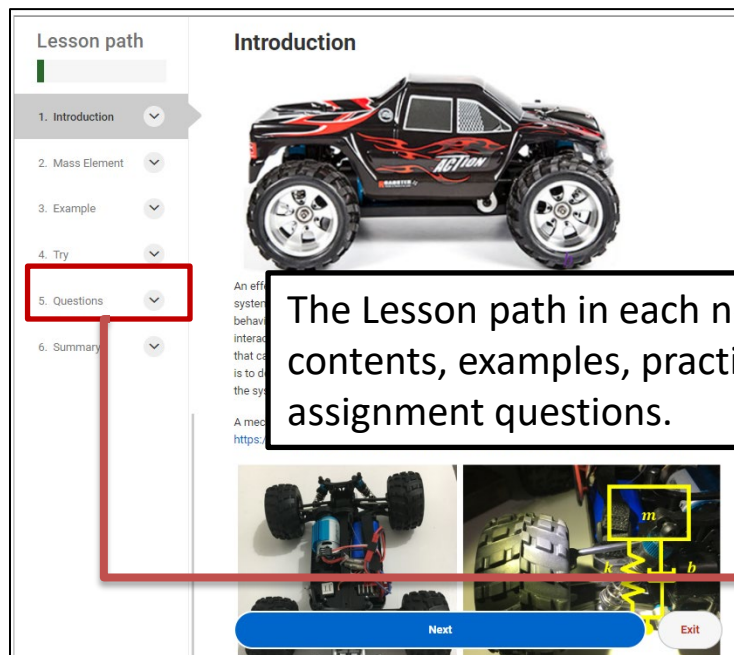
# Realizeit is an adaptive learning platform that can be integrated into Canvas via its assignment tools.

Home  
Modules  
Grades  
Academic Support

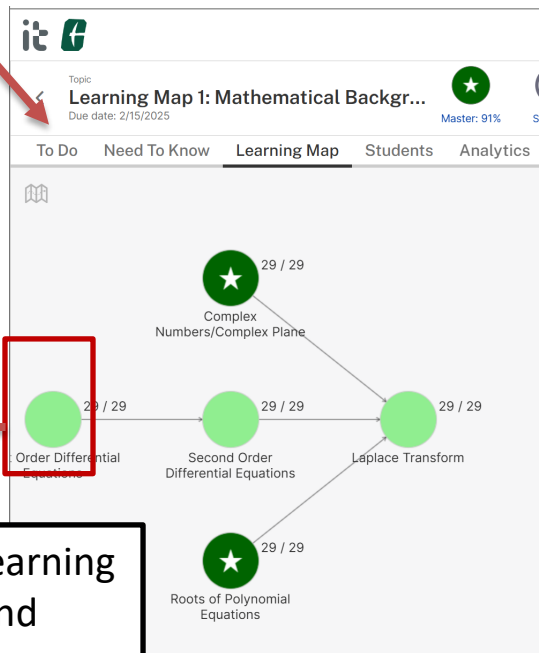


Clicking a Realizeit assignment link in Canvas takes students straight to the corresponding unit in Realizeit. Each link can be set for a specific assignment or exam

Each assignment module is built as a graph of connected nodes addressing prerequisites. As soon as one node is completed, the next unlocks, ensuring mastery at every step.



The Lesson path in each node contains learning contents, examples, practice problems and assignment questions.



Grades will be transferred to Canvas automatically

Home  
Modules  
Grades  
Academic Support

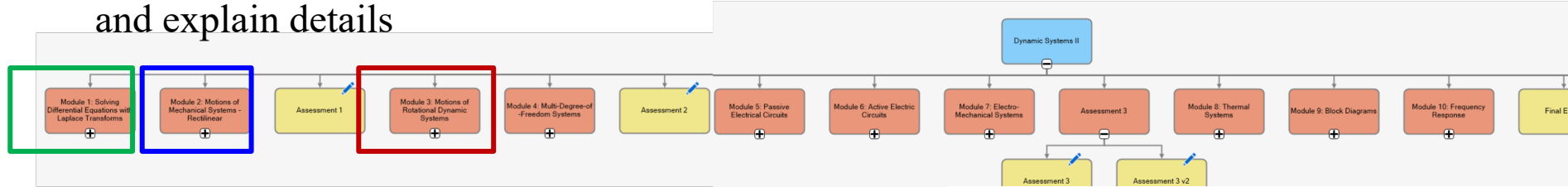
Realizeit:  
Mathematical  
Background &  
Laplace Transforms  
HW Assignments

Jan 23 by 11:59pm

0 / 100

# The entire course was reimagined.

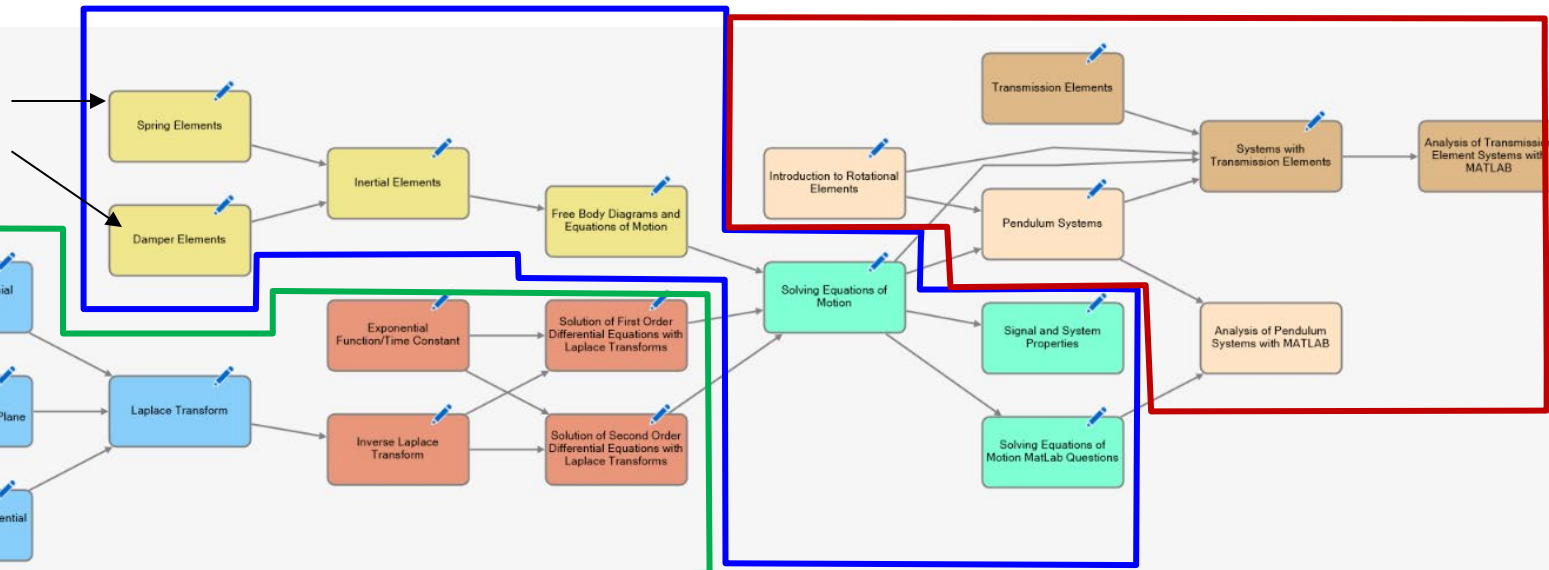
- Mapped key concepts into a hierarchical curriculum
- Aligned lessons and objectives through a prerequisite network. The network contains modules which are focused on key concepts. Multiple nodes per module to break down and explain details



## Module 2 – Motion of Mechanical Systems: Rectilinear

## Module 3 – Motion of Mechanical Systems: Rotational

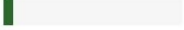
Nodes



## Module 1 – Solving Differential Equations with Laplace Transforms

# Instructional Content in Realizeit

- Instructional content was created using our own and open-source materials.
- Content is delivered in multiple formats—videos, files, and questions—embedded in a single page so students stay within the systems.
- Today, with platforms like ChatGPT, this part of the work can be done much faster and more efficiently.

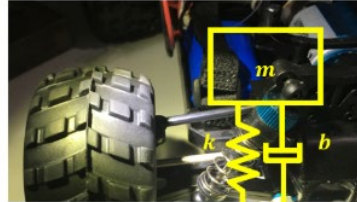
**Lesson path**  
  
1. Introduction ▾  
2. Mass Element ▾  
3. Example ▾  
4. Try ▾  
5. Questions ▾  
6. Summary ▾

## Introduction



An effective way to model dynamic systems is with lumped parameter elements. We divide systems into their essential interacting components, and we “lump” the dominant physical behavior of each component or element into a simplified mathematical model. By modelling the interactions between the elements, we describe the system dynamics with a differential equation that can be solved using Laplace transform methods. The goal of the lumped parameter approach is to describe a dynamic system with a linear differential equation model that adequately describes the system behavior without introducing unnecessary complication.

A mechanical example of a dynamic system is an R/C vehicle as below (also see textbook: [https://link.springer-com.librarylink.unc Charlotte.edu/chapter/10.1007/978-1-4614-9293-1\\_3#Fig1](https://link.springer-com.librarylink.unc Charlotte.edu/chapter/10.1007/978-1-4614-9293-1_3#Fig1)).



**Next** **Exit**

**Question 3** 

**Description of Gears**

This problem analyzes gears which are a transmission element that transform rotational motion to rotational motion but modify the respective angular velocities and moments. A detailed drawing of the gear system is shown below. A rigid shaft (gray) is attached to a first rotational inertia (blue) and a first gear (yellow). The shaft is constrained by bearings (gray) to rotate about a fixed axis. The first gear (yellow) engages a second gear (red) which is attached to a rigid shaft and a second rotational inertia (blue). The second shaft is constrained by bearings (gray) to rotate about a fixed axis. The gear teeth mesh without slipping. View the animation below to better understand the motions of the system.

[See the system in action](#)

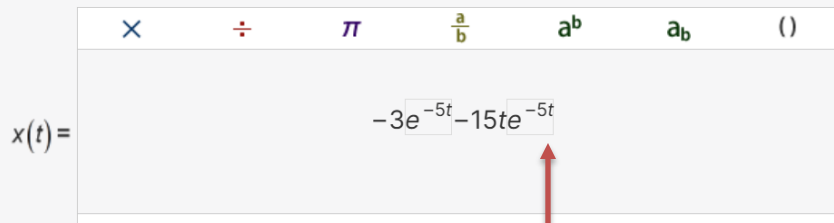


# Questions in Realizeit

## Student View

We express the equation in this form because each variable— $c_2$ ,  $\sigma$ ,  $\omega$ , —has a distinct physical interpretation, which is a key focus in Dynamics 2.

Enter  $x(t)$  below.



$x(t) = -3e^{-5t} - 15te^{-5t}$

We define the range of variable to ensure the answer will have the form of

$$x(t) = A_1 e^{-p_1 t} + A_1 t e^{-p_1 t}$$

We call these systems critically-damped where the system does not oscillate.

Other possible form  $x(t)$

$$x(t) = A_1 e^{-p_1 t} + A_2 e^{-p_2 t} \text{ (over damped)}$$

$$x(t) = A_1 e^{-p_1 t} (\cos \psi t + \sin \psi t) \text{ (under damped)}$$

## Behind-the-scene

### Step 1: Problem Definition

Use Laplace transform to solve the differential equation  $c_2 \ddot{x} + 2c_2 \sigma \dot{x} + c_2 (\sigma^2 + \omega^2) = 0$   
With the initial conditions of  $x(0) = x_0$  and  $\dot{x}(0) = v_0$  for  $x(t)$

### Step 2: Variable Selection

Variables are defined as

- $c_2$  is a random integer number from  $c_{2,\min}$  to  $c_{2,\max}$
- $\sigma$  is a random integer number from  $\sigma_{\min}$  to  $\sigma_{\max}$  but  $\sigma \neq 0$
- $\omega$  is a random integer number from  $\omega_{\min}$  to  $\omega_{\max}$  but  $\omega \neq 0$
- $x_0$  and  $v_0$  are random integer numbers from  $x_{0,\min}$ ,  $v_{0,\min}$  to  $x_{0,\max}$ ,  $v_{0,\max}$  but  $v_0 \neq 0$

```
% Clear environment
clear; clc;
syms s t X x0 v0 c2 sigma omega

% Define the roots of the characteristic equation
a = 1;
b = 2*sigma;
c = sigma^2 + omega^2;
p = solve(a*s^2 + b*s + c == 0, s);
p1 = simplify(p(1));
p2 = simplify(p(2));

% Laplace domain solution
X = ((s + 2*sigma)*x0 + v0) / ((s + p1)*(s + p2));
x_t = ilaplace(X, s, t);
x_t = simplify(x_t);

% Match to form a1*exp(-p1*t) + a2*exp(-p2*t)
syms A1 A2 real
expr = A1*exp(-p1*t) + A2*exp(-p2*t);
eqns = [subs(expr, t, 0) == x0, ...
        subs(diff(expr, t), t, 0) == v0];
sol = solve(eqns, [A1 A2]);
```

| A  | B     | C     | D  | E  | F  | G  | H   | I   |
|----|-------|-------|----|----|----|----|-----|-----|
| c2 | sigma | omega | x0 | v0 | p1 | p2 | a1  | a2  |
| 6  | 4     | 3     | -1 | 1  | -4 | -4 | -1  | -1  |
| 3  | 2     | 1     | 1  | -1 | -2 | -2 | 0.5 | 0.5 |
| 3  | 4     | 1     | 1  | 0  | -4 | -4 | 0.5 | 0.5 |
| 1  | 5     | 1     | -1 | -1 | -5 | -5 | -1  | -1  |
| 4  | 5     | 1     | -2 | -2 | -5 | -5 | -1  | -1  |
| 4  | 5     | 2     | 1  | 1  | -5 | -5 | 0.5 | 0.5 |
| 3  | 4     | 1     | 2  | -2 | -4 | -4 | 1   | 1   |
| 2  | 5     | 2     | 1  | -1 | -5 | -5 | 0.5 | 0.5 |
| 2  | 4     | 1     | 0  | 0  | -4 | -4 | 0   | 0   |
| 2  | 5     | 3     | -2 | -2 | -5 | -5 | -1  | -1  |
| 2  | 5     | 0     | -3 | 0  | -5 | -5 | -3  | -1  |

## Step 1: Problem Definition

Use Laplace transform to solve the differential equation  $c_2\ddot{x} + 2c_2\sigma\dot{x} + c_2(\sigma^2 + \omega^2) = 0$

With the initial conditions of  $x(0) = x_0$  and  $\dot{x}(0) = v_0$  for  $x(t)$

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- $\omega$  is a random integer number from  $\omega_{\min}$  to  $\omega_{\max}$  but  $\omega \neq 0$
- $x_0$  and  $v_0$  are random integer numbers from  $x_{0,\min}$ ,  $v_{0,\min}$  to  $x_{0,\max}$ ,  $v_{0,\max}$  but  $v_0 \neq 0$

Such that the results have a form of

$$x(t) = A_1 e^{-p_1 t} + A_2 t e^{-p_1 t}$$

## Step 3: Solution Generation

A Matlab code is written and the values of  $A_1, p_1, A_2, p_2$  for a given  $c_2, \sigma, \omega, x_0, v_0$  and an excel sheet is generated as source to Realizeit 

For graph-based problems, we generated several meaningful parameter sets and behind the scenes, Realizeit checks each student's solution against all valid answers!

Question 3

**Description of Gears**

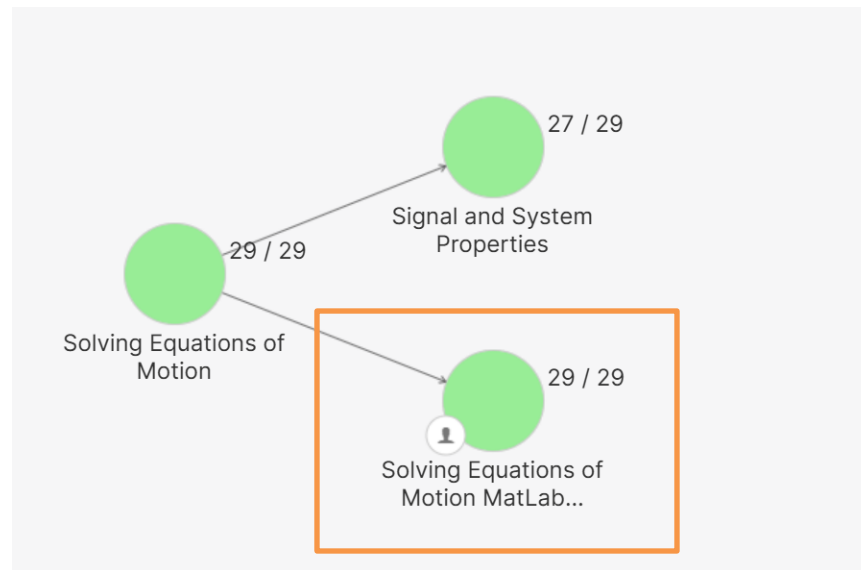
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[See the system in action](#)

The input is  $m(t) = 30.3 \cdot u(t)$  N-m. The initial condition is  $\omega_1(0) = 0$ . Which of the following four graphs best represents the motion of the system's input side?

Student Solution

Match Solution Number 83



- **MATLAB Grader** – for simple, auto-graded code within the platform.
- **Uploading Matlab Files** – for complex scripts that instructors review manually.

## < Solving Equations of Motion MatLab Questions

Main Details History Extra

5 submissions required. 5 submissions uploaded.

Submission: 1

### MATLAB Problem 1

Submission (Jan 29, 4:56 PM)

Score

1 / 1

on Jan 29, 4:56 PM

Upload

Home

Grader

Exam

5 submissions required. No submissions uploaded yet.

Submission: 1

MATLAB Problem 1

Upload

Students select the upload button to see the question

### Problem 1: Simple Harmonic Oscillator

In the previous node, Problem 1, you solved the problem below for  $x(t)$ . Retrieve your answer now. In order to better understand the following in MATLAB Grader: (1) generate a time vector "ts" with a maximum value of  $4T$ , a minimum value of 0, and a step size of  $T/10$ ; (2) plot "xs" versus "ts". Follow the instructions carefully.

Click "Run Script" and ask yourself the following questions.

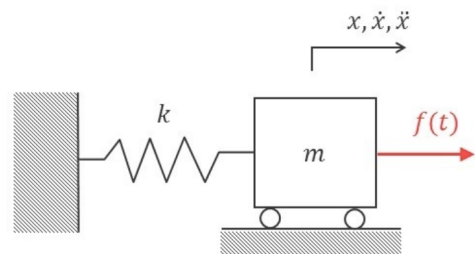
Can I see the period of the oscillation in my plot and does it make sense?

Do I see that my solution is not damped?

When you are confident your code is correct, click "Submit" and MATLAB Grader will check your solution. When you are

[My Solutions >](#)

The Matlab questions are the same questions in the previous nodes. Therefore, students already know the parameters and answers, but they are asked to code it up for better understanding.



Script ?

Save

Reset

MATLAB Documentation

Open Item in MATLAB Online

?

```
1 % READ THE FOLLOWING INSTRUCTIONS BEFORE CODING
2 % Do not define the statements "clear all" and "clc"
3 % Assign your time values in a variable 'ts' and displacement values in variable 'xs'.
4 % When using the plot command assign the the command to a variable f (i.e.) use f = plot(ts,xs);
5 % The evaluation algorithm will search for the variables ts, xs and f to evaluate your code.
6
```

## Your Script

Save Reset MATLAB Documentation

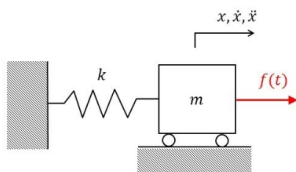
```

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4 % When using the plot command assign the the command to a variable f (i.e.) use f = plot
5 % The evaluation algorithm will search for the variables ts, xs and f to evaluate your
6
7 % Parameters
8 T=0.42;
9
10 % Time Vector
11 ts=[0:T/110:4*T];
12
13 % Displacement vector
14 xs=-4*cos(15*ts)-(8/5)*sin(15*ts);
15
16 % Make the plot
17 f=plot(ts,xs);
18 xlabel('t (s)')
19 ylabel('x(t) (m)')
20 axis([0 max(ts) min(xs) max(xs)])
21 grid
    
```

The scripts have some instructions to make it implementable in Malab graders

Known parameters from problems that the student have already solved in other nodes

Run Script ?



```

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Save Reset MATLAB Documentation

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16 % Make the plot
17 f=plot(ts,xs)
    
```

Run Script

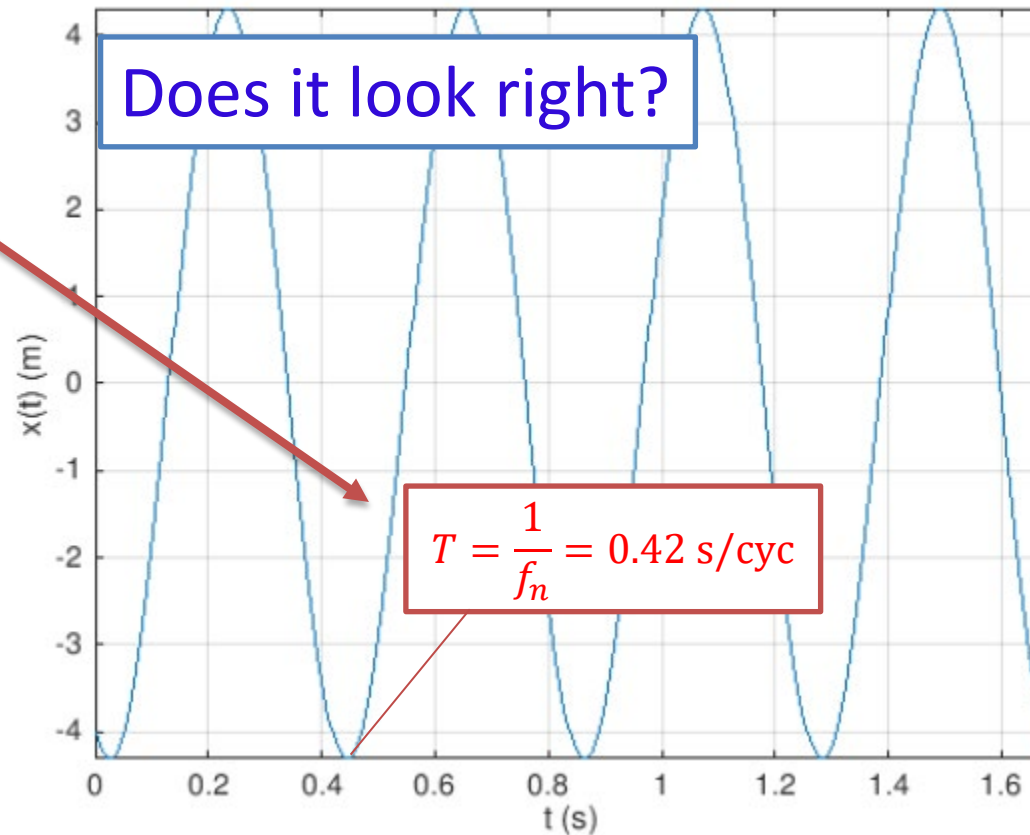
# Plot the solution in MATLAB Grader.

## Your Script

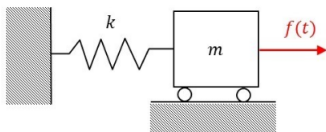
Save Reset MATLAB Documentation

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19 ylabel('x(t) (m)')
20 axis([0 max(ts) min(xs) max(xs)])
21 grid
```

Does it look right?



$$T = \frac{1}{f_n} = 0.42 \text{ s/cyc}$$



```
% READ THE FOLLOWING INSTRUCTIONS BEFORE CODING
% Do not define the statements "clear all" and "clc"
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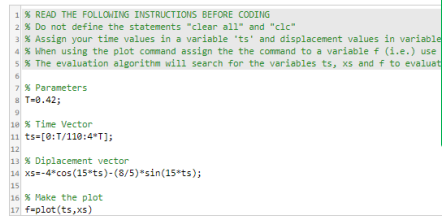


## Your Script

```
1 % READ THE FOLLOWING INSTRUCTIONS BEFORE CODING
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```

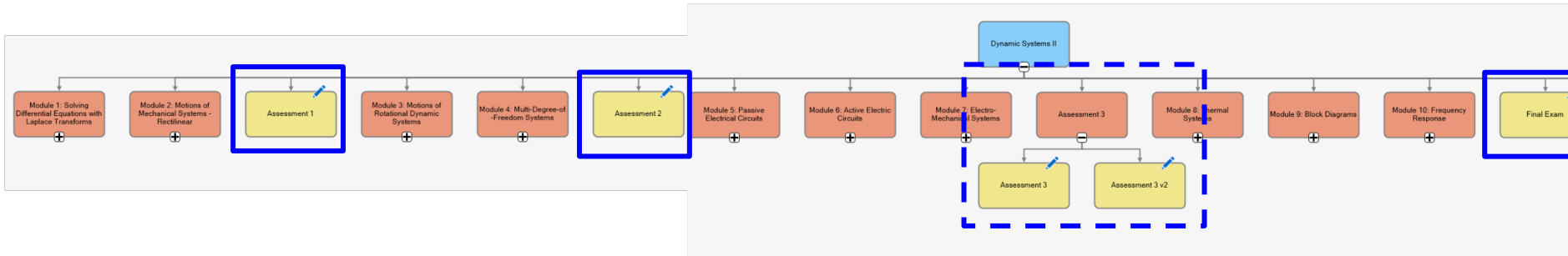
Submit

Submit



# Exams in Realizeit

We created exam modules as standalone modules outside the adaptive path to assess mastery independently of practice progress. The exam modules only consist of several questions.



Different students get different values—same structure, same difficulty.

Exams can be set with a **strict timer**, **single attempt**, and **optional lockdown browser** if needed.

| Total     | Part 1   | Part 2   |
|-----------|----------|----------|
| 11 Points | 6 Points | 6 Points |

Question number 1

Consider the function  $X(s)$  in the Laplace domain.

$$X(s) = \frac{4}{14s + 140}$$

Rearrange the expression into the following form.

Available time  
2:29:52  
/ 2:30:00

Question number 7

Upload a single PDF file with the Certification and your work for the problems. Use the file "Assessment 1 Certification and Supplemental Work.docx" to generate your PDF file.

| # | Description                          | Type | Attachment    | Edit                 |
|---|--------------------------------------|------|---------------|----------------------|
| 1 | Upload the PDF file only accept: pdf |      | No attachment | <a href="#">Edit</a> |

☐ I don't know

The exams are auto-graded but we ask students to submit their work for partial credits.

# Realizeit allows student support by tracking their performance and providing timely interventions via its analytic tool

Topic  
< **Learning Map 1: Mathematical Background and Laplace Transforms**  
Due date: 2/15/2025

Master: 91%  29/29   
Students

To Do Need To Know Learning Map Students **Analytics**

- > Student performance
- > Students learning progress by lesson
- > May need intervention (11)
- > Specific problems (3)
- > May need challenge (3)
- > Completed lessons (5)

**Objective:** Investigate the use of targeted interventions to improve student performance and engagement.

### Student Groups:

- **High Achievers:** Strong performers with consistent progress.
- **Struggling Learners:** Students significantly behind in coursework.
- **Inconsistent Performers:** Began work but struggled to complete it.
- **Whole Class:** General interventions sent to all students.

**Interventions:** Personalized messages offering assistance, motivational support, and sample problem solutions, tailored to each group's needs.

**Evaluation Metrics:** Submission rates, grades, engagement levels, and overall student satisfaction.

# Realizeit allows student support by tracking their performance and providing timely interventions via its analytic tool

Topic  
 < **Learning Map 1: Mathematical Background and Laplace Transforms**  
 Due date: 2/15/2025

Master: 91% 29/29 Students

To Do Need To Know Learning Map Students **Analytics**

> **May need intervention (11)**

| Pairing | Last work      | Time spent            | Est Time left | Lesson covered | Learning progress | Composite score |
|---------|----------------|-----------------------|---------------|----------------|-------------------|-----------------|
| Mar 28  | 3 hrs 12 mins  | 5/5<br>Lesson covered | Expert: 80%   | 80%            |                   |                 |
| Jan 30  | 4 hrs 47 mins  | 5/5<br>Lesson covered | Master: 94%   | 94%            |                   |                 |
| Jan 23  | 10 hrs 45 mins | 5/5<br>Lesson covered | Master: 95%   | 95%            |                   |                 |
| Mar 25  | 11 hrs 25 mins | 5/5<br>Lesson covered | Exp           |                |                   |                 |
| Jan 21  | 6 hrs 6 mins   | 5/5<br>Lesson covered | Mas           |                |                   |                 |

- Observation 1:** considerable effort, yet no perfect score.
- Observation 2:** too much time spent.

Messaging Students to ask if they need any help?

(targeting struggling Learners or inconsistent performers)

11:04 PM  
 RI suggested you might need some assistance with HW5. Are there any specific areas that I can help with

11:56 PM

I was having early trouble but got it figured out. Now, I am having trouble with the second MATLAB problem. It tells me that the plot is incorrect for the following code, but the plot looks to be correct. Do you have ideas why this might be?  
 Thank you!

Realizeit allows student support by tracking their performance and providing timely interventions via its analytic tool

Topic

# Learning Map 1: Mathematical Background and Laplace Transforms

Due date: 2/15/2025

Master: 91% Students

29/29

To Do Need To Know Learning Map Students Analytics

> Specific problems (3)

| Lesson                              | Learning progress | Errors |
|-------------------------------------|-------------------|--------|
| Second Order Differential Equations | Improving: 40%    |        |
| Complex Numbers/Complex Plane       | Completed: 60%    |        |
| Laplace Transform                   | Completed: 60%    |        |

7:43 PM

Thank you Professor, I kept making silly mistakes, for example signs and using the wrong inverse Laplace. I am still not 100% clear on the meaning when the solution is bounded or unbounded.

I created a short note on topics of HW2. Please review them if needed.

Creating videos or concise lecture notes (with ChatGPT) that highlight the primary steps in solving problems and the core concepts of the material. (targeting whole class and struggling learners)

Messaging students and let them know about additional resources

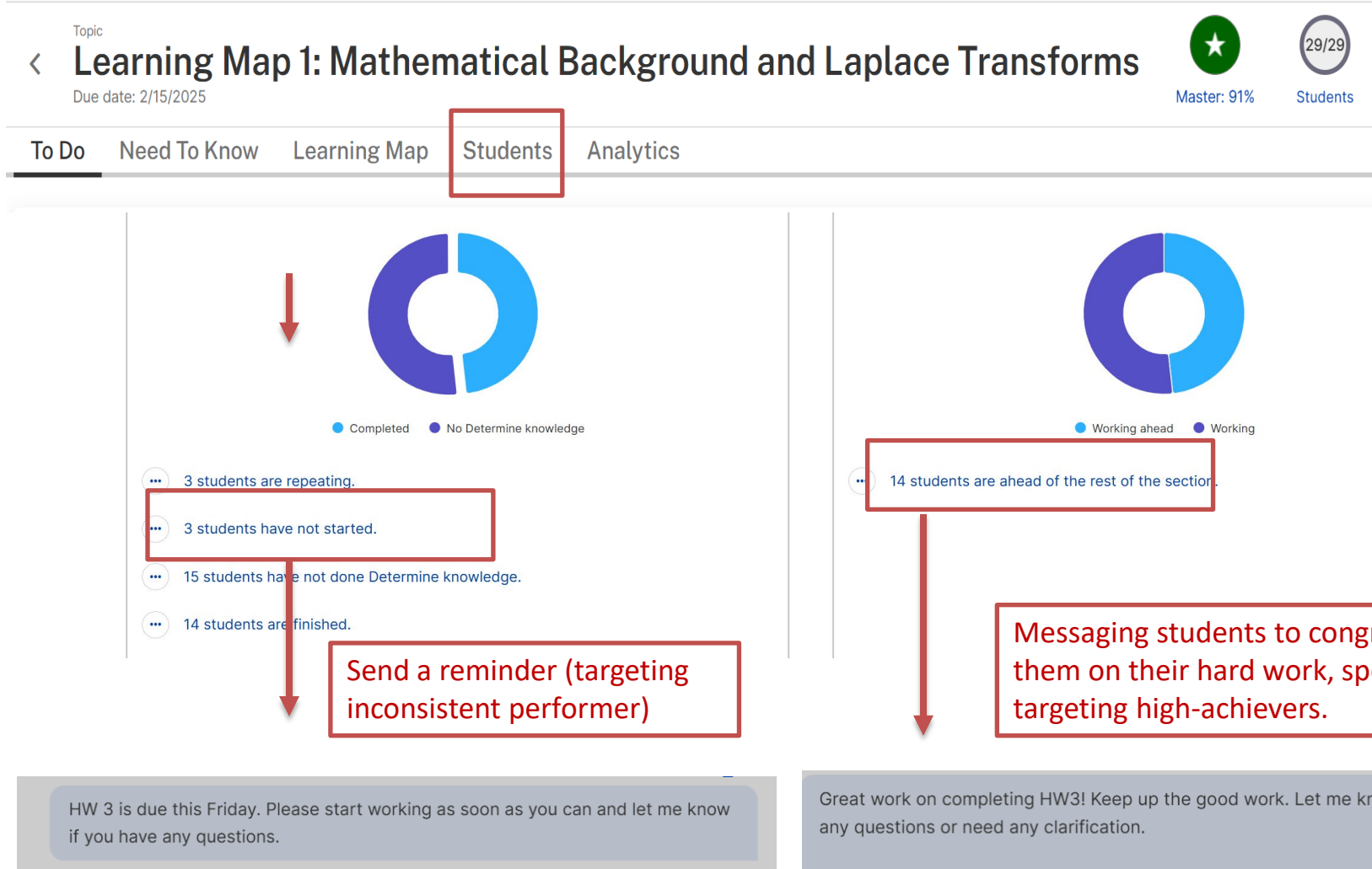
Short Notes on HW2  
0 pts

videostonHW3\_part1\_FBD.mp4

videostonHW3\_part2\_differentialEqs..mp4

**Observation** Quickly spot the specific nodes and content areas where students struggle

# Realizeit allows student support by tracking their performance and providing timely interventions via its analytic tool



# Realizeit allows student support by tracking their performance and providing timely or interventions via its analytic tool

Topic  
 < **Learning Map 7: Multiple-Degree-of-Freedom**  
 Due date: 3/23/2025

Master: 90%    14/29 Students    Watch    Instructor Toolbox

| To Do         | Need To Know | Learning Map                                                                      | Students           | Analytics                                                                                      |
|---------------|--------------|-----------------------------------------------------------------------------------|--------------------|------------------------------------------------------------------------------------------------|
| No time       | 1 hr 20 mins |  | 0/4 Lesson covered |  Mastery     |
| 1 hr 33 mins  | 40 mins      |  | 2/4 Lesson covered |  Master: 92% |
| 4 hrs 57 mins | 40 mins      |  | 2/4 Lesson covered |  Master: 94% |
| 1 hr 59 mins  | 40 mins      |  | 2/4 Lesson covered |  Master: 99% |

**Observation:** Although students can use emojis as an indicator on their emotions for achieving their goals, they rarely update their responses or engage with emails regarding their emoji status. After completing HW1, there is **minimal** change in the emoji patterns.

51%

I noticed that you selected the "frustrated" emoji. Please let me know if there's anything I can do to help. I encourage you to review the short notes I posted on Canvas related to HW1, as well as the video on complex numbers.

Let me know if you have any questions—I'm happy to assist!



# Personal Connections with Students Matters: Adaptive Learning Makes It Scalable

## My Reviews in Spring 2024

- My biggest issue was less with the course and more with the realizeit course. I just feel **it took way too much time** out of my week to complete in comparison equivalent homework assignments.
- I really enjoyed the content and lectures in this course, but felt like the Realizeits were **buggy** and kind of confusing at times.

## My Reviews in Spring 2025

- **Online resources were excellent.**
- The professor related the problems to real life so it was easier to understand the concepts. Going over problems during class helped a lot too. **RealizeIt is great** because it reinforces what was learned in class.

# Conclusions

- Students value personalized messaging and targeted interventions.
- Realizeit's analytics help instructors quickly identify student challenges.
- While the initial setup may be resource-intensive, the system is highly sustainable—and often requires minimal resources to maintain.

## New Challenges when AL is implemented

1. Some students attend class less, relying on online resources.
2. Need deeper real-world context and application to maintain student's interest and attendance.

## Future Plans

- Promote attendance with bonus/challenge problems.
- Continuously refine interventions (or even automate some of them), sharing best practices.
- Expand adaptive learning to other engineering and STEM areas.



# **Thank you very much!**

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