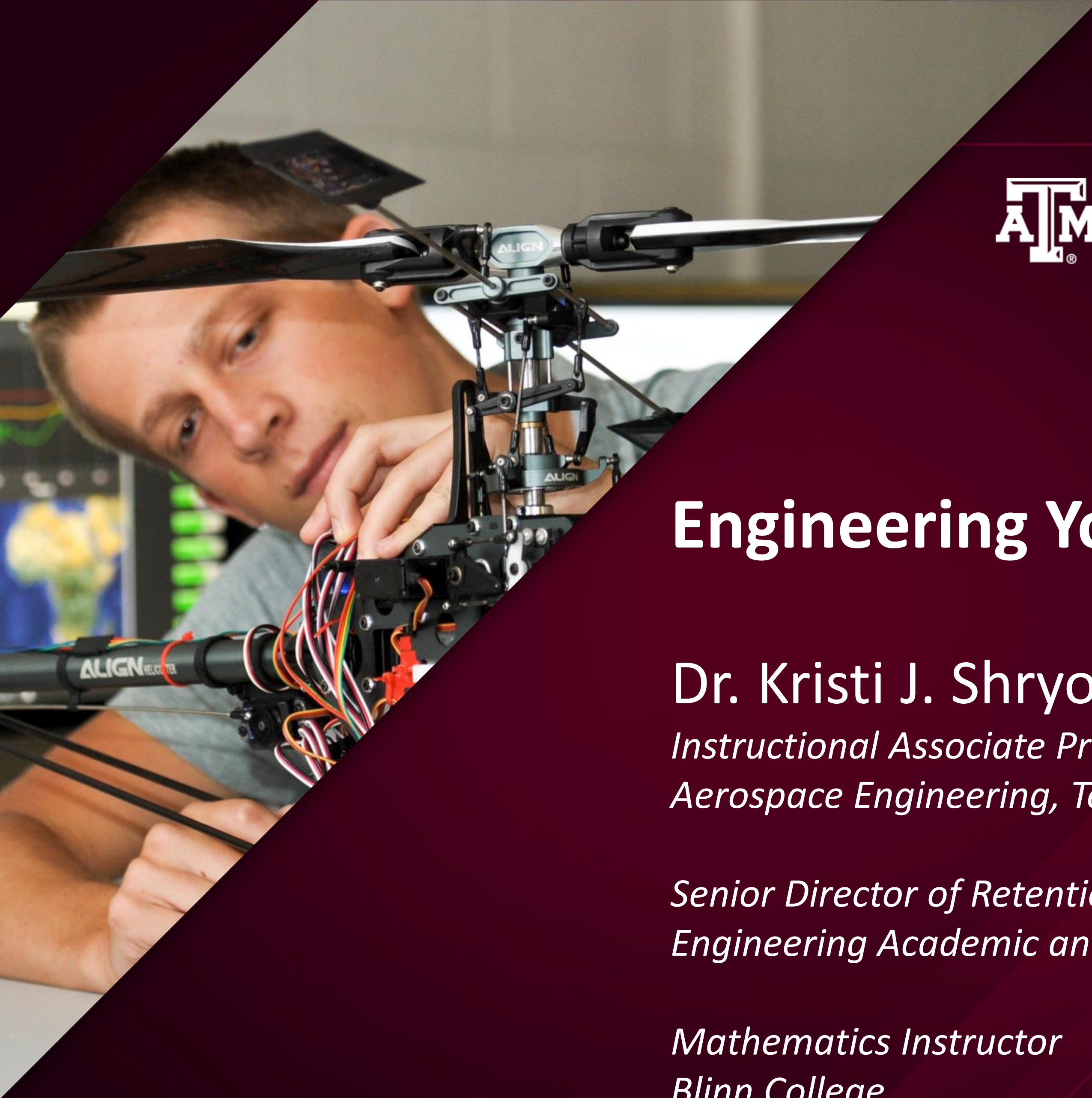

AEROSPACE ENGINEERING
TEXAS A&M UNIVERSITY

Engineering Your Math Class!

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AEROSPACE ENGINEERING 75 years 1940-2015

Outline

- Introduction
- Engineering Design Process
- Examples
- Next Steps

Apprehensions?

TEKS

111.32 Algebra I

- 111.32.a.3 – Function concepts
- 111.32.a.5 – Tools for algebraic thinking
- 111.32.a.6 – Underlying mathematical processes
- 111.32.b.1.d – Represent relationships
- 111.32.b.2.d – Model and predict
- 111.32.b.8.b – Linear functions

111.33 Algebra II

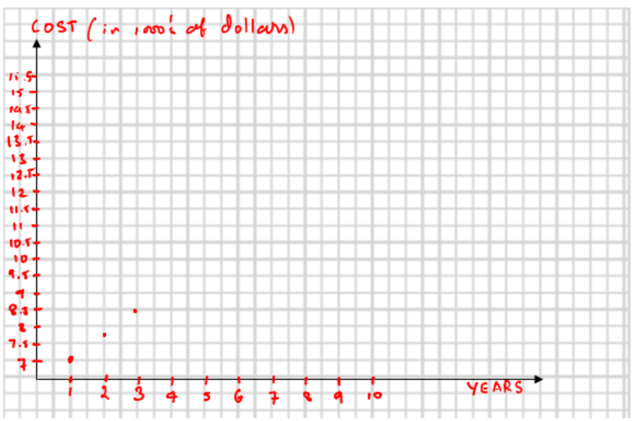
111.35 Precalculus

Math beyond just the Numbers

Representation of information

- Tables of numbers
- Graphs

Year	Cost Calculation	Actual Cost
1	7000	7000
2	7000*1.1	7700
3	7700*1.1	8470
4	8470*1.1	
5		
6		
7		
8		
9		
10		



Math beyond just the Numbers

Converting verbal to symbolic

- The IRS is investigating you for tax fraud. According to the documents that you provided, you invested some of your total savings of $10,000 in a CD, which gives an interest of 4%, and the rest in a money market account with interest of 1.5%. The IRS looks at your bank statement and sees that your money market account has given you an interest income of $15. How much total money should you have?

- A company makes boxes with a square base and a height that is 1/3 the base. Obtain an expression for the area of cardboard needed and the volume of the box.

Compute Average Velocity

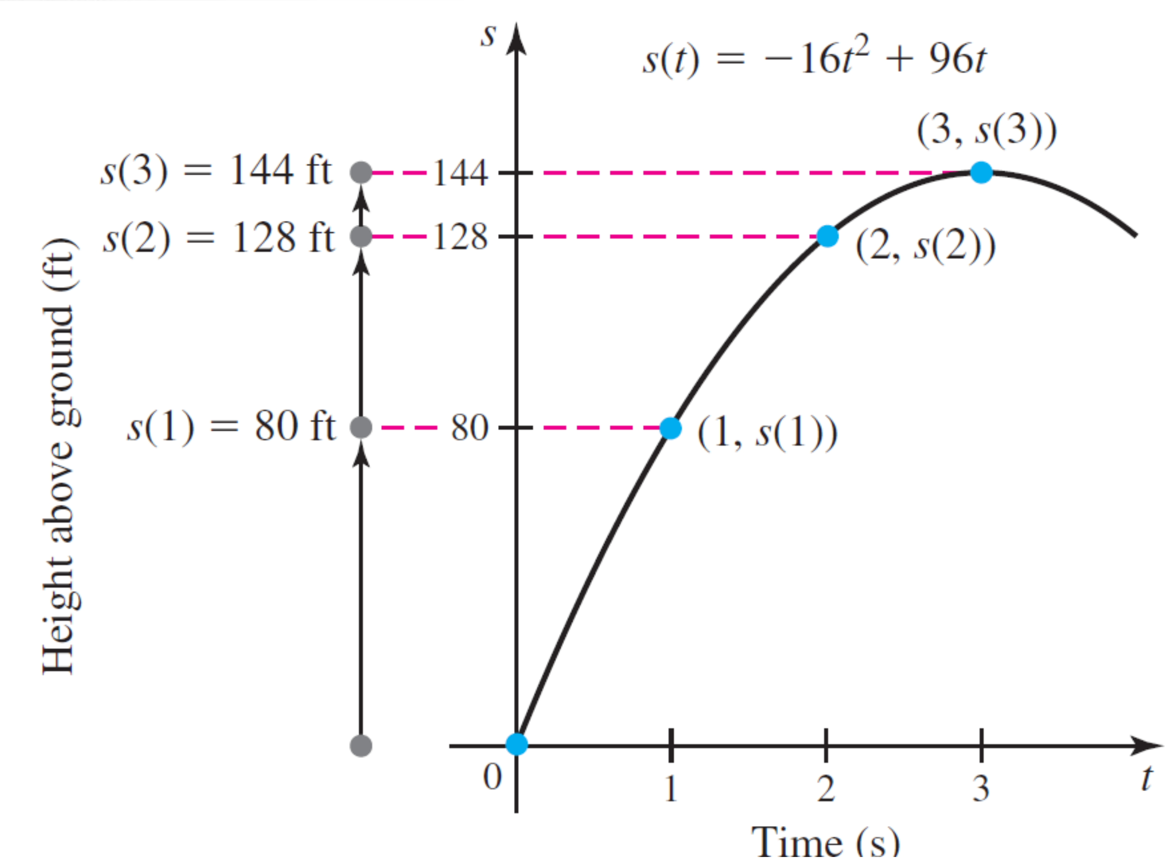
A car travels 110 miles in 2 hours.

What is its average velocity?

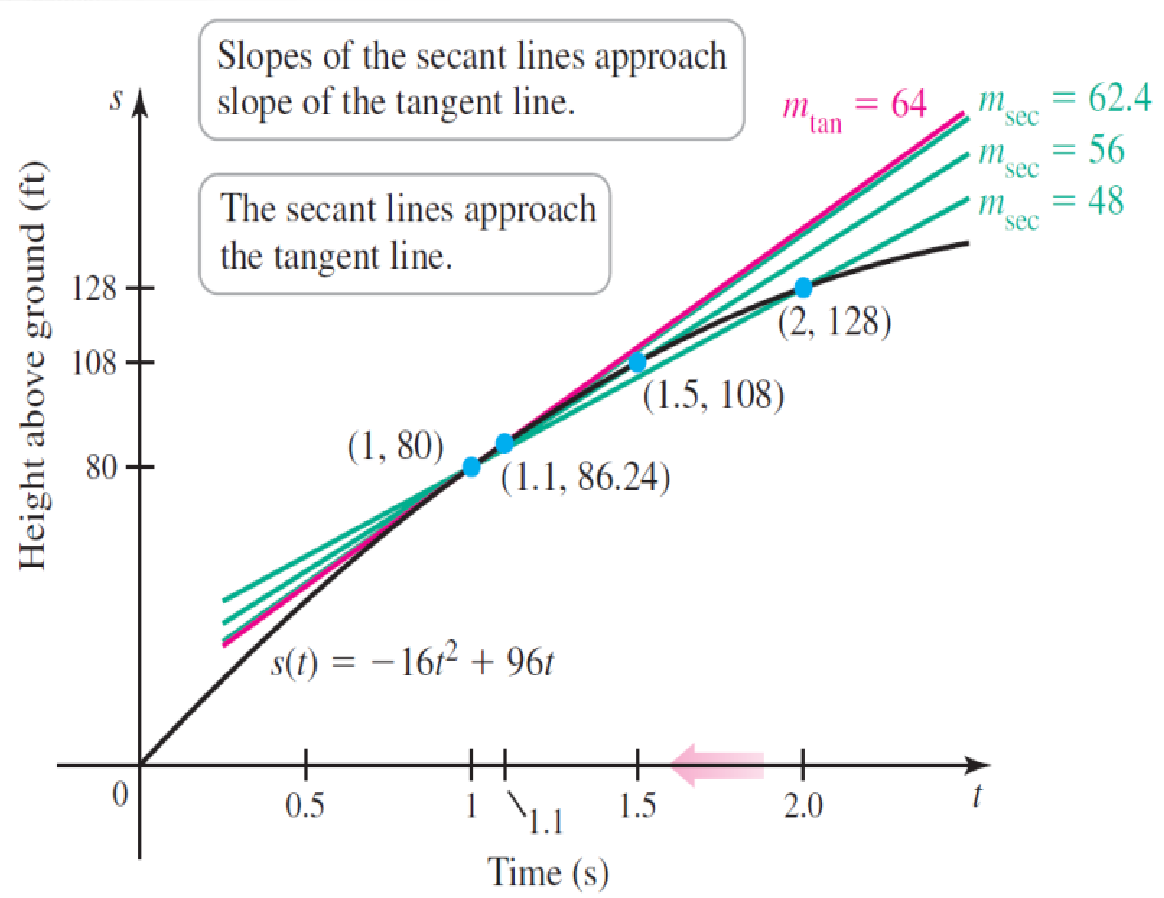
How do you depict this graphically?

Provide a story for the figure.

What is given? What can you determine?

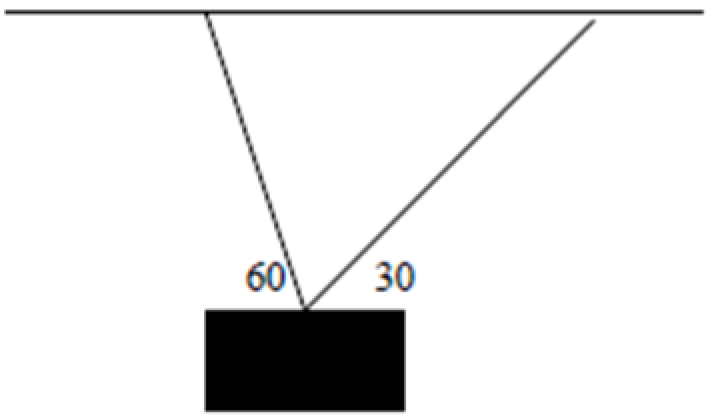


Tangent Line vs. Secant Line



Adding Engineering to Math

EXAMPLE: Two ropes are used to suspend an 80 pound weight as shown. Find the magnitude of the tension in each rope.



What is a real-world scenario for this?

The Link Between Physics and Geometry

*Or…*How to Use Mathematics to Build Things and Keep Us Safe!

Introduction:

- One of the greatest achievements of mankind was the discovery (or invention) of a deep link between how our reality operates (from black holes and supernovas down to earthworms and viruses) and various aspects of mathematics. While exploration of this link is a continuing endeavor of science, the exploitation of this link for practical purposes is at the heart of engineering.

Detail the Connection:

- In this project, we will exploit the following observation:
- When a body is *immobile*, the forces when "drawn'' end to end will always form a closed loop. Thus, if there are three forces acting on the body, they will form a triangle; four will form a quadrilateral, etc.

The Link Between Physics and Geometry

*Or…*How to Use Mathematics to Build Things and Keep Us Safe!

Provide Motivation:

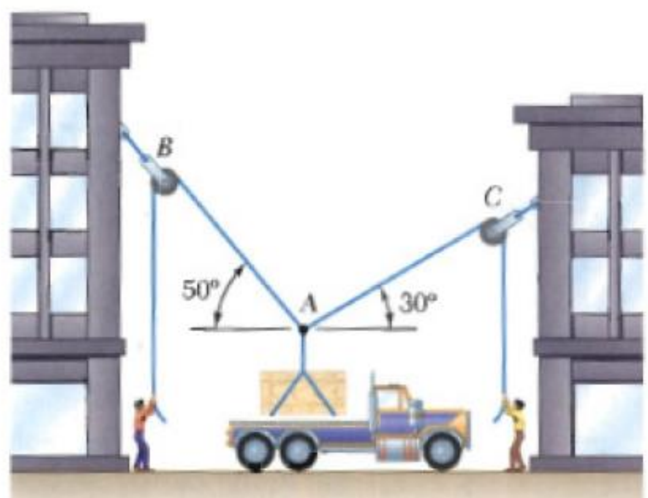
- Using constructive geometry and trigonometry to find unknown forces: prediction!
- Up to now, we have just talked about representation of forces. Now since we know that for a body to be stationary, all the forces if drawn end to end will form a closed loop, we can use this information to find unknown force by enforcing the loop closure conditions.
- This is one of the main uses of trigonometry in engineering!

The Link Between Physics and Geometry

*Or…*How to Use Mathematics to Build Things and Keep Us Safe!

Apply the Concept:

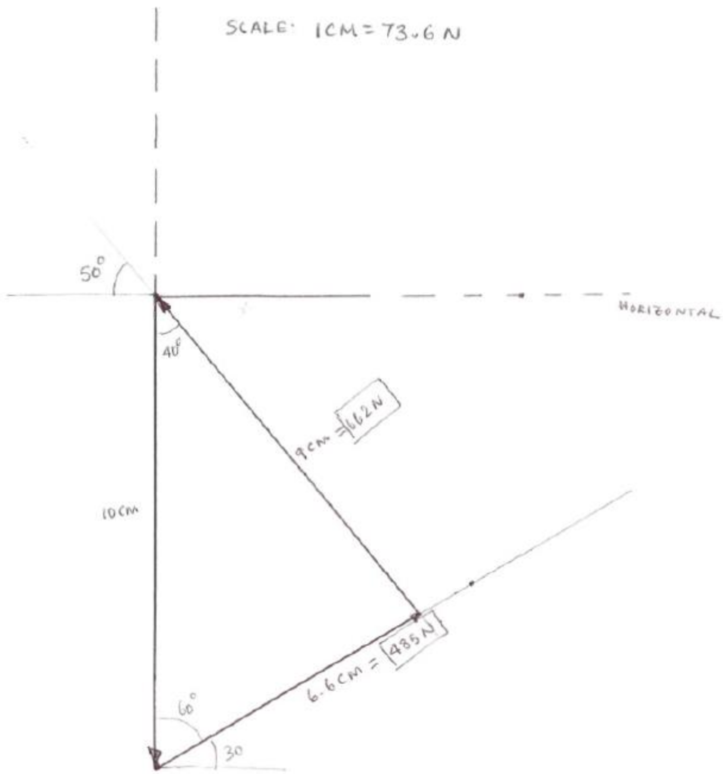
- Consider the 736 N crate shown in the figure. This is lying between two buildings and is now being lifted onto a truck. The ropes will break, and the crate will come crashing down if the force (called the rope tension or simply tension) exceeds 650N. Therefore, is it safe to do this operation?



The Link Between Physics and Geometry

*Or…*How to Use Mathematics to Build Things and Keep Us Safe!

Graphical vs. Trigonometry ~ even use technology:



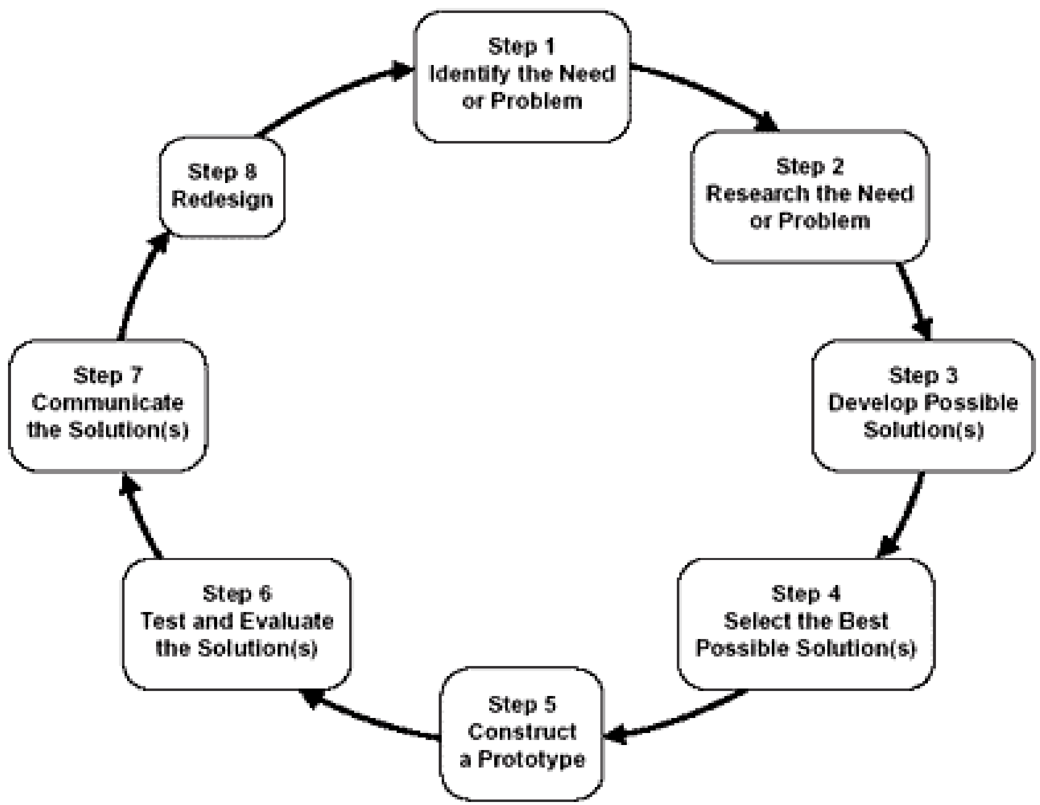
If you know the law of sines, then you can say:

$$\frac{T_{AB}}{\sin 60} = \frac{T_{AC}}{\sin 40} = \frac{736}{\sin 80}$$

Þ $T_{AB} = 647N, \quad T_{AC} = 480N$

Thus, the ropes will not break! We are safe.

Steps of the Engineering Design Process



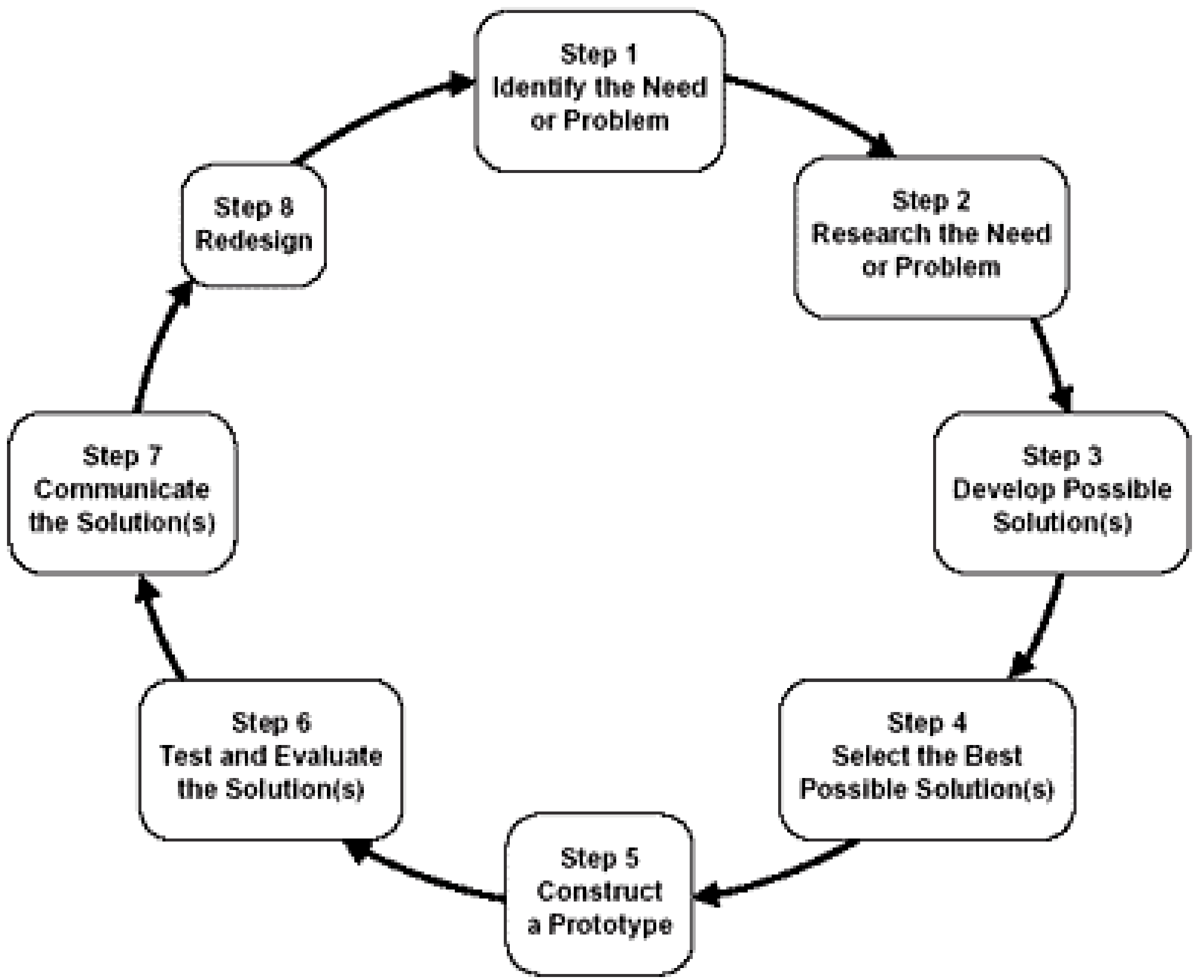
Structural Modeling: Design, Optimization, and Teamwork

Project Description

The following project requires participants to use good planning, teamwork, and engineering problem solving techniques. The overall objective is to design and build a new building structure that meets or exceeds minimum specifications supplied by the customer while maximizing overall profit. The following information explains the specific objectives of the project.

The design process should be a tool for the engineering student to use when approaching design problems and should guide them from design specifications to a final solution. While there are many design structures that could be implemented, the iterative design structure will be used for this project. See Figure 1 for the steps involved in the engineering design process.

Figure 1: Steps of the Engineering Design Process



Step 1: Define the Problem

You and your team have been asked to design and build a model of a structure that is very robust and can withstand high structural loading. The specifications provided by the customer for your model are as follows:

- Each model must be at least 36 inches tall and support a weight equivalent to 10 pennies for at least 30 seconds. The winning prototype will have the maximum profit while adhering to the design constraints provided below.

Design Constraints:

- Height: Earn $100,000 for building a structure that is 36 inches tall. *Bonus:* $2,000 per inch above 36 inches.
- Strength: The structure must support 10 pennies at a height of at least 36 inches for at least 30 seconds without falling. After this, teams can load additional pennies onto their structure. *Bonus:* $500 for each additional penny loaded.
- Speed: The structure should be built within 25 minutes. Structures built in more than 25 minutes will be charged $2,000 for each additional minute. *Bonus:* $1,000 for each minute under 25.
- Material Costs: 3"x5" index cards are $1,000 each with a 100 card limit. Tape is $5,000 per roll. Scissors are $5,000 per pair.

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Profit Calculation Worksheet

Costs

Cards purchased _________ x $1,000 each = ___________________

Rolls of tape used _________ x $5,000 each = ___________________

Pairs of scissors used _________ x $5,000 each = ___________________

Time used beyond 25 minutes _________ x $2,000 each = ___________________

Total Costs: ___________________

Revenue

Successfully built structure (Yes = $100,000, No = $0) = ___________________

Height – Additional height (inches above 36) _________ x $2,000 each = _______________

Strength – Additional pennies (beyond 10) _________ x $500 each = __________________

Speed – Available time not utilized (minutes under 25) _________ x $1,000 each = ______

Total Revenue: ___________________

Total Profit = Total Revenue – Total Costs = ___________________

Step 2: Research

Evaluate online sources, textbooks, etc. for building structure ideas. Make sure you understand the limitations listed below.

- Teams will not be allowed to purchase additional cards or return cards once construction begins.
- Teams will be charged for the number of cards bought, not the number actually used, (i.e., no returns).
- If tape is used, it cannot be affixed to any other structure, (i.e., tables, chairs, floor, ceiling, etc.).
- The structure height will be determined by measuring the elevation of the highest card where loading will occur above the surface upon which the structure is built.
- If failure occurs during loading of additional pennies, teams forfeit the opportunity to earn a strength bonus. In other words, teams should know the capacity of their design prior to the day of competition.

Step 3: Generate Ideas

In your planning session(s), develop a design plan and list of construction materials. Each team must decide how many cards they want to 'buy' and whether or not they will use tape and/or scissors.

Step 4: Analyze and Compare

Using your knowledge of structures, along with any additional research you performed, determine the best solution to be built.

Step 5: Build a Prototype

Each team will build a model in class using the specifications provided. Prior to this build, a typed design plan must be submitted at the beginning of the build. The design plan is evidence that you actually did 'design' and 'planning' for this activity, instead of just improvising on the day of the contest. The design plan will be graded for completeness, neatness, and accuracy to actual competition results, and should include…(given them specifics, including dimensional drawing, details on activities during each phase of design process, etc.).

Step 6: Test your Design

Each team will test their model by attaching weights (pennies) to the top of the structure.

Step 7: Communicate Results

Observations should be documented in the design report you will submit individually one week after testing. Sharing results with other engineers is how improvements in the information base, manufacturing techniques, and engineering technologies are made!

Step 8: Redesign and Improve

An important part of your Conclusions section of your design report will be to discuss any improvements you would make if another round of testing were to occur. Ideally, the design process is a cycle and should be repeated to improve efficiency and performance of your design. For sake of this class, we will go through the design process only once to give you a feel for the steps involved.

Landing an Airliner

Topics and skills: Derivatives, Chain Rule, Integration

Step 1: Define the Problem

With the reduction in air traffic controllers in many regional airports, the need has increased to provide pilots with the need to model the landing of an aircraft.

Step 2: Research

What are the implications of landing at airports in a flat rural area or even a mountainous area?

Landing an Airliner

Step 3: Generate Ideas

Figure 1 displays a flight path for an aircraft with the airport being placed at the origin. What constraints are important in determining the function for the flight path of an aircraft?

Step 4: Analyze and Compare

How many assumptions did students determine?

What type of function can satisfy all four conditions?

Step 5: Build a Prototype

Based on the four constraints, begin with a cubic polynomial. Assume that $y(x) = ax^3 + bx^2 + cs + d$.

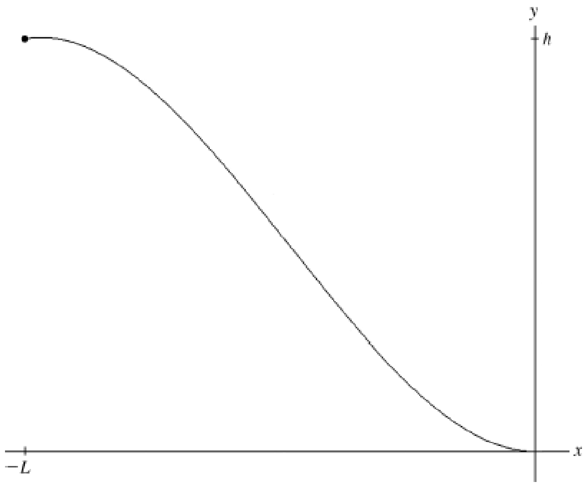


Figure 1

Landing an Airliner

Step 6: Test your Design

Verify that the function determined satisfies the constraints. Assume L = 100 miles and h = 6 miles, (approximately 31,700 feet).

Step 7: Communicate Results

Write-up, graphs

Step 8: Redesign and Improve

How do different geological conditions at airports affect the model developed?

How long will your iPod last?

Topics and skills: Integration, Graphing, Improper Integrals

Step 1: Define the Problem

None of the many gadgets we use—laptops, iPods, skateboard wheels—last forever; they all have finite lifetimes. Predicting those lifetimes is generally difficult, however. A battery used in devices may last two years or two months, depending on the conditions in which it is used (hot, cold, wet, dry), the number of times it is recharged, or many other factors. Because of the variability and randomness involved in the lifetime of a gadget, the best we can do is talk about the *average lifetime*. For example, the average lifetime of a 60-watt compact fluorescent light bulb is rated as 6000 hours; some bulbs do not last that long, and others last longer. How can we compute these average lifetimes?

How long will your iPod last?

Step 2: Research

Ask the students to collect data from 20 owners on the number of hours their iPod operated before it failed.

Step 3: Generate Ideas

Compile and graph the data.

Possible questions to ask:

- What would each axis represent?
- If the vertical axis is the fraction of devices that have failed for a given number of hours, what would be minimum and maximum values be on the vertical axis?

How long will your iPod last?

Step 4: Analyze and Compare

Let's say that data from 1000 owners who carefully kept a record of how many hours their iPod operated before it failed was collected and graphed as shown in Figure 1.

Possible questions to ask:

- How closely does this match the data from the students?
- Why might their be differences?
- How does the sample size come into play?

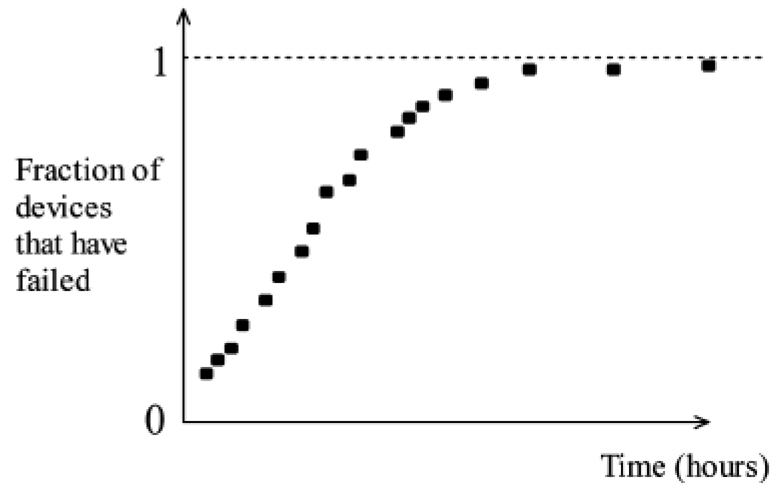


Figure 1

How long will your iPod last?

Step 5: Build a Prototype

It is easier to work with the data if it is approximated by a continuous function.

Possible question to ask:

- What type of function does this graph resemble?

The distribution of failure times for many devices is approximated by functions of the form $F(t) = 1 - e^{-\lambda t}$, where λ is a positive constant.

Step 6: Test your Design

Graph $F(t)$ with λ = 0.2, 0.5, 1.0, 1.5, and 2.0, and $0 \leq t \leq 10$.

How long will your iPod last?

Step 7: Communicate Results

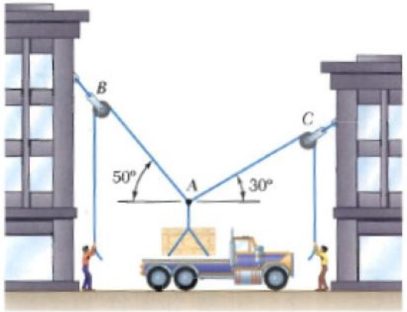
Describe how the graph in Figure 1 differs from the graphs individually developed. Also, describe how the graphs change with λ. Do larger values of λ correspond to devices that have shorter or longer lifetimes?

Step 8: Redesign and Improve

Describe how the average lifetime of iPods might be improved.

Apply the Engineering Design Process

- Consider the 736 N crate shown in the figure. This is lying between two buildings and is now being lifted onto a truck. *What type of material would be best for the cables in this operation?*



Specific tensile strength of various materials

Material	Strength (MPa)	Density (g/cm³)	Specific Strength (kN·m/kg)	Breaking length (km)
Concrete	12	2.30	4.35	0.44
Rubber	15	0.92	16.3	1.66
Copper	220	8.92	24.7	2.51
Polypropylene	25-40	0.90	28-44	2.8-4.5
Brass	580	8.55	67.8	6.91
Nylon	78	1.13	69.0	7.04
Oak	90	0.78-0.69	115-130	12-13
Magnesium	275	1.74	158	16.1
Aluminium	600	2.80	214	21.8
Stainless steel	2000	7.86	254	25.9
Titanium	1300	4.51	288	29.4

Other considerations? Factor of safety?

Your Turn!

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Questions?

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