<u>'Aunt Ada's Treehouse'</u>

Delivery (Contents)

Mech 12 – Strength of Materials; Team Formation Questionaire (Fall 2015)

Name: ____

Hometown: ______________________________________H.S. GPA (& year of graduation):__________________

Hobbies/Interests:____

Do you live on/near campus or do you commute:____

Preferred times for team meetings and group work (please circle as many as possible):

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Morning	Morning	Morning	Morning	Morning	Morning	Morning
Afternoon	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon
Evening	Evening	Evening	Evening	Evening	Evening	Evening

What is your field of engineering study and why did you choose that field (i.e. what about it interests you)?

Have you ever been a leader/officer in an organization? If so, in what capacity?

Would you be willing to be a team leader in this course?

Have you used any of the following software programs (please circle):

AutoCAD, SolidWorks (or similar model construction software)? YES NO

Excel? YES NO

Matlab? YES NO

Word? YES NO

PowerPoint? YES NO

Circle one choice below to complete the following sentence as best describes you. I am at Lehigh mostly to______.

Study Party An Even Blend

NOTE: Information provided will assist in forming good functioning teams. I would appreciate you answering every question, but you may skip any question without repercussion. Please be as generous as possible with preferred times available for group work.

<u>Mech 12 Computational Project #1a, Fall 2015</u>

(Due September 4, 2015)

You have a very wealthy, incredibly brilliant, and wildly eccentric aunt, Aunt Ada. Aunt Ada made her fortune as a highly innovative engineer who embraced her entrepreneurial side, spinning numerous of her inventions into profitable businesses. Aunt Ada is now enjoying quieter, golden years on her vast property in the Poconos and one of her recent delights was to learn that you enrolled in an engineering program at Lehigh University.

Though well loved, Aunt Ada has a reputation in your family for championing some pretty wild ideas. As such, you are not surprised to receive from her an invitation to her "cabin in the woods" for the weekend to hear a business proposition she has for you. Intrigued, you head on up into the mountains to visit Aunt Ada in her mountain estate.

After you settle in and get into technical discussions, Aunt Ada reveals she wants to construct what can only be described as an epic tree house. In fact, the design she has in mind is sufficiently large and the location she is considering on her property is sufficiently constrained that there are no natural trees into which the tree house can be built. Having concluded that an artificial tree needs to be constructed, she is offering you the job of designing the trunk of the tree. She points out that all of the mount points for the tree house as well as for artificial branches and leaves will be such that the trunk will effectively be loaded in a purely 1D condition. Aunt Ada goes on to say that, if your design is successful, she will pay you the full cost of a four-year education at Lehigh along with, "a little something to help you get off the ground after school."

You take the job so your first phase of work is to determine relevant parameters dictating the design of the trunk. This first phase is to be done as an individual exercise; you should create a bulleted or numbered list of relevant things that must be considered in designing the trunk. In other words, what questions need to be answered and, with those answers, what do you need to do to ensure a good design. A single item in your list can be as short as a few words or as long as a paragraph. You should be as quantitative as possible and you should justify your assumptions or assertions. If necessary, include references at the bottom of your list.

"The more I study, the more insatiable do I feel my genius for it to be."* - *Ada Lovelace

Rubric for student outcome 1a: Tree Trunk Considerations

	Performance Indicators	Below standard	Meets standard	Above standard	Exemplary performance
1	Identification of appropriate mechanical constraints	Lists a few basic mechanical properties to be considered (E, A, height, etc.)	Provides several relevant factors that have been covered in class (yield stress, strains)	Elaborates on class topics and provides their importance in terms of the treehouse.	Introduces concepts not yet covered in class and/or considers material properties, and how they impact design.
2	Consideration of environment & Sustainability	Fails to mention environmental factors affecting the design.	Considers basic environmental factors (rainfall, climate)	Elaborates on different aspects of the environment; considers relation to mechanics.	Elaborates on different environmental factors and relates them to the design/material impact.
3	Consideration of client	Fails to recognize the needs of the client.	Considers generic client needs (cost, lifespan of structure, safety)	Considers needs specific to the client in question (use of structure, physical demands)	Elaborates on nonessential client desires such as aesthetics of the design and ease of construction.
4	Societal Impact (Curiosity & Project Engagement)	Shows little time commitment; only basic mechanical needs considered.	Due consideration has been given to mechanical elements. Only factors relevant to this single structure are considered.	Considered factors show evidence of interest to the immediate impact of the structure on its surroundings.	Evidence shown of interest in the modularity of the structure and/or long term impact on society.

<u>Mech 12 Computational Project #1b, Fall 2015</u>

(Due September 9, 2015)

This next part of the project is a team-based activity. You must hold at least one face-to-face meeting prior to submitting your team response and your team submission must include minutes from the meeting; additional team interaction may occur via electronic means or face-to-face meetings as needed. Note that meeting minutes do not count in word count limits described below but minutes themselves should be 100-150 words. Meeting minutes should be a team writing effort.

Use your individual lists of trunk design metrics as well as discussion from lecture to assemble your team's formal response. Again, the response you are formulating is to the approximate question, "What are the most salient design metrics for the tree trunk, why are those the most salient, quantitatively what do you recommend for each of your identified metrics, and why do you make each recommendation?" ***While this response should again be a bulleted list, you must use complete sentences within each bullet.***

Similar to before, a single item in your list can be as short as a single sentence or as long as a paragraph. You should be as quantitative as possible and you should justify your assumptions or assertions. If you would like to include supporting calculations, they may be done by hand and scanned; however, be sure the presentation looks neat and professional. Supporting calculations will not count toward your word count (see below); however, you should refer to them in the corresponding bullet and such discussion will count in your word total. If necessary, include references at the end of your response (again, they do not count toward the word count).

Each member of each team must write a roughly equal contribution to the response. Each student's contribution must be in the range of 200-250 words and the student must be identified at the start of her or his writing. This means each team's response should be in the range of 600-750 words (for 4 person teams, that range is 800-1000 words). Again, meeting minutes, supporting calculations, and references do not count in the word count. Responses outside these prescribed word counts will have points deducted. ***All team members will share the same grade on the response.***

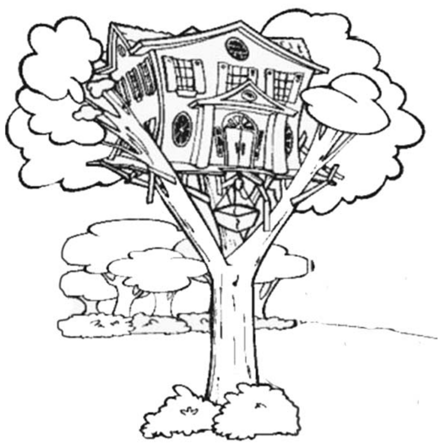
"Understand well as I may, my comprehension can only be an infinitesimal fraction of all I want to understand.*"* - *Ada Lovelace*

Rubric for student outcome 1b: Evaluation of Most Important Criteria

	Performance Indicators	Below standard	Meets standard	Above standard	Exemplary performance
1	Verification of Important Criterion	Choices are not supported with any numerical data or mechanical variables.	Choices show evidence of mechanical consideration; basic quantitative data provided.	Choices show mechanical consideration with formulas and dependent variables. Quantitative examples provided.	Choices are mechanically supported through equations and variables, quantitative examples provided, formula manipulation evident.
2	Treehouse Impact	Criteria's relationship to treehouse design not explained or not understandable.	Criteria's relationship to treehouse design is mentioned, but not with detail.	Criteria's relationship to treehouse design is discussed, with supporting scenarios.	Criteria's relationship to treehouse design is foremost; scenarios and formulas revolve around how the design is impacted.
3	Presentation of possible solutions	No possible solutions are provided to the problems posed by the criteria.	A single solution is provided to the problems posed, may not be explained.	A single solution is provided to the problems, and explanation is given as to how this would counteract the issue.	Multiple solutions are provided to the problems posed; reasoning behind solutions are provided, solutions may be compared in terms of functionality.
4	Societal Impact (Curiosity & Project Engagement)	Solutions/criteria show little time commitment; only basic mechanical needs considered.	Solutions/criteria show some research beyond purely mechanical considerations.	Solutions/criteria relate to or emphasize effects on surrounding environment, client needs, or other external factors.	Solutions/criteria consider, and are hinged around the impact of the structure on its surroundings and client needs. Feasibility in larger society is discussed.

<u>Mech 12 Computational Project #1c, Fall 2015</u>

(Due September 14, 2015; 25 points)



This next part of the project is an individual activity.

Create a thorough list of the steps one takes to complete finite element analysis of the stress, strain, deflections, and reaction forces in/on a 1D bar structure. ***I am not looking for complete sentences in this exercise; instead, I am looking for clear instructions, including relevant equations in pseudo code language where applicable. We will discuss what I mean by "pseudo code" in class and I will post an example on Course Site.***

For this part of the project, you are not really thinking about Aunt Ada and her epic tree house. What I am looking for here is an algorithm description for a computer code that solves a 1D FEM problem. That is why you are encouraged to cast your instruction list in terms of equations and, where possible, pseudo code. You will see in class (and from my example) that it may be easier to write pseudo code by hand, rather than with a word processor. If you submit hand written work, please be sure it is neat and clear enough to be fully legible.

If you think about Quiz #2, the instructions for that sort of laid out the steps to solving a 1D FEM problem; however, your algorithm description, or flowchart, should be complete and it should indicate how to get the stress and strain in every element as well as the reaction forces. Obviously, before you do that, you have to solve for unknown nodal displacements. But, before you do that, you have to set up the reduced, global K matrix, as well as the reduced U and F vectors. And before you do that, you have to … etc, etc.

You should start at the very beginning: what must be defined and what rules apply for governing that information? For example, we know that a node must be defined at each end of the entire 1D bar structure; furthermore, a node must exist wherever an external force is applied. Similarly, a node must exist at any point where the area or Young's modulus changes discontinuously. We may decide that, for accuracy, we need more nodes (i.e. more elements) but there are rules governing the minimum number of nodes/elements. Once all necessary starting information is defined, describe each step that must be taken to proceed from defining the problem to completing the analysis of the problem. Also, as already discussed, you should use words in your flowchart (or algorithm description) but lean heavily toward equations and pseudo code. You should assume that the bar structure can only be fixed to a wall at one or both of its ends and nowhere between.

Rubric for student outcome 1c: Pseudo-Code Breakdown

	Performance Indicators	Below standard	Meets standard	Above standard	Exemplary performance
1	Identification of variables	Fails to provide relevant variables or only identifies major variables.	Identifies most of the major and minor variables.	Identifies most major and minor variables, and provides indication of values and equations.	Identifies major and minor values, provides values and equations; discusses variables to store/access data (arrays or matrices)
2	Organization of code into steps	Gives no or only a vague overview of steps to perform 1D analysis.	Gives overview of steps necessary to perform 1D analysis, mentions use of if statements for handling conditions and loops for iterations.	Indicates most necessary steps for analysis, mentions use of coding mechanisms, connects relevant variables to steps.	Elaborates on all necessary analysis steps, provides thorough descriptions of code to be utilized, puts variables into coding context.
3	Code/Process Functionality	Overview does not provide enough information to demonstrate understanding of analysis process.	Shows general understanding of steps to be taken to run the analysis.	Shows understanding of 1D FEM analysis. Code-specifics may have minor errors.	Demonstrates thorough understanding of 1D FEM. Code examples are variable specific and have few errors.

<u>Mech 12 Computational Project #1d, Fall 2015</u>

(Due September 18, 2015)

Part 1d of the project is a team-based activity.

It is now time to propose to Aunt Ada a collection of tree trunk designs along with a justification for each proposed design. As we discussed in class, this now essentially becomes a description of A(x), E(x), and P(x); however, as we also discussed, there is quite a bit of context behind these selections and you should therefore provide such context. Each student must prepare a proposal to include in the team's report and the total text contributed by each student must be in the range of 150 – 200 words. Each student must be identified at the start of her or his writing.

At least one face-to-face meeting is required prior to submission of this part of the project. Your team should use the meeting to devise a strategy behind your collection of proposals; basically the idea is you want to provide Aunt Ada with some choice in the final design and you want a game plan, if you will, behind the choices presented to her. This strategy should be summarized for Aunt Ada in a paragraph that starts the team's report; the summary should be in the range of 100 – 150 words. Creating the introductory paragraph (your strategy summary for Aunt Ada) should be a team writing effort; as such, you do not need to create minutes from the meeting – only the introductory summary.

Supporting figures are encouraged; hand sketches are fine but, as always, please submit as professional a quality as you can. The number of words on figures should be minimal; that said, words on figures do not count toward your word total. If necessary, include references at the end of your team report (again, they do not count toward the word count).

Proposal reports outside the prescribed word counts will have points deducted. ***All team members will share the same grade on the response.***

*"*Understand well as I may, my comprehension can only be an infinitesimal fraction of all I want to understand.*"* - *Ada Lovelace*

Rubric for student outcome 1d: Treehouse Designs and Specifications

	Performance Indicators	Below standard	Meets standard	Above standard	Exemplary performance
1	Mechanical considerations and functionality	Designs show little consideration of mechanical properties; little to no support of design decisions.	Designs consider multiple mechanical properties and provide some quantitative reasoning for decisions.	Designs consider all highly relevant mechanical properties and show thorough quantitative support for decisions.	Designs consider mechanical properties beyond those necessary, provide quantitative support for major mechanical decisions and qualitative support for minor considerations.
2	Variation of Design	Designs are all very similar, with only minor variations.	Designs differ in more than one way, but may revolve around changing only these ways (ie. All designs have a different material and shape, only).	Designs show variety in several different ways and have only basic overlap; each design offers a unique benefit.	Designs vary in many aspects and consider variation to the basic needs of the consumer. Each design has its own benefits.
3	Clarity of Design Concept	Design is hard to visualize; design decisions are difficult to understand.	Design is clear and understandable; supporting decisions are explained.	Design is easy to visualize, decisions are clear in relation to overall design.	All aspects of design are understood; supporting figures are provided, decisions are supported through design visual.
4	Teamwork & Coherence of Presentation	No introduction or explanation of logic behind different designs. No theme evident.	Introduction may be provided explaining how designs relate, or each design mentions its benefits/drawbacks. May be hints of a theme.	Introduction provides overview of rationale to designs. Benefits of design are clear. Designs may overlap one another in the theme; not completely balanced.	Introduction provides overview of rationale to designs. Benefits of design are clear and there is a clear theme and leveraging of ideas.
5	Societal Impact (Curiosity & Project Engagement)	Designs show little to no consideration beyond the mechanical.	Designs are considerate of the client needs and show some evidence of research beyond purely mechanical aspects.	Designs emphasize consideration of the client, impact on the surroundings, and how to adjust to those needs. Research has been done.	Designs emphasize consideration of the client and the surroundings, as well as modularity to overall society. Specific research is demonstrated.

Dear Team 3,

So sorry to sound informal with that team name – that's Professor Webb's doing, not mine! I wanted to tell you first hand how delighted I was with your recent proposal for the tree trunk to support my "epic tree house". It has been a joy to me to know that my favorite offspring of my dear brother is engaged in engineering pursuits and that you were excited to help out with the trunk design. I am also happy to hear that you assembled a team of other engineering students to help you in this activity; more brains are better, I've often found.

Anyway, I am hoping herein to describe my final design decisions, many of which are based on the suggestions made by your team. For some details, I used inspiration from your proposal but made changes to better suit my desires. I'm hoping that, with what is described below, you will know very specifically the total length of the trunk I desire as well as the material to use throughout the design. I believe that Professor Webb would call these things L_{tot} and E(x). I also describe the levels of the tree house I want to mount to the trunk and where I would like them to go; thus, I am hoping you can turn that into specific information about the external loads on the trunk due to the house. Professor Webb would point out that these are contributions to the overall P(x). Given that information, I am asking your team to optimize the cross-section of the trunk in a manner that I describe further below. So I am asking you to optimize A(x). To repeat, I provide below some specifics about the cross-section I desire and I even put on my engineer's hat to suggest a way for you to constrain your optimization exercise (i.e. to make it more tractable). Please read what I provide below and formulate questions your team has – Professor Webb intends to discuss this activity extensively with you so your questions will be answered as fully as possible.

First, after perusing your suggested trunk heights, I would like the total height to be 120 ft –a bit higher than you suggested. I really like Ryan's suggestion of steel so we will use that material throughout. We'll use a 300 series, corrosion-resistant steel; as Professor Webb would point out, for your purposes, that means $E(x) = 29 \times 10^6$ psi for all values of x. He is a stuffy one, isn't he?! Anyway, we are very lucky to be working with a master artist/designer who will create for us a faux bark to be mounted on the steel trunk. He's designing branches, faux leaves – his work is stunning and this is going to look great. However, you don't need to worry about that part, except to know that this thing will not look completely out of place among the pines and firs up here! The weight added by those aesthetic details will be relatively small so we will ignore it, except for the fact that we will use a factor of safety of 2.5 on the yield stress and critical buckling load. More on that below.

Now, about those suggested house designs: great work! Really: just wonderful! I hate to choose favorites among your designs but I really resonated with the multiple levels proposed by Doyle. I must confess that I now desire a larger total square footage than I originally imagined (and much larger than what any of you proposed!). An old friend of mine pointed out that, to host the sort of parties I am known for, I will want more space. Your proposals inspired me to spread that space out among multiple levels! Absolutely charming suggestions, really. So here's what I'm thinking: please plan for a large, two-story structure somewhat lower down, with ~5500 ft^2, as well as a large single story level whose top coincides with the top of the trunk; that last level should be ~2000 ft^2. I would like 10-foot tall ceilings so you should plan for each story to be of sufficient height to accommodate this. The two-story level should be two times whatever height you determine for each story, of course! When you calculate the total force applied on the trunk by each level, you should then divide that among 3 mount points for the single story level and among 5 mount points for the two-story level. Our consulting structural engineer has said you should evenly distribute the mount points along the length of the trunk occupied by the given level. By the way, your team was really outstanding in addressing loading on the trunk by the houses in your proposed designs – nice analysis (I just want a bigger house now)!

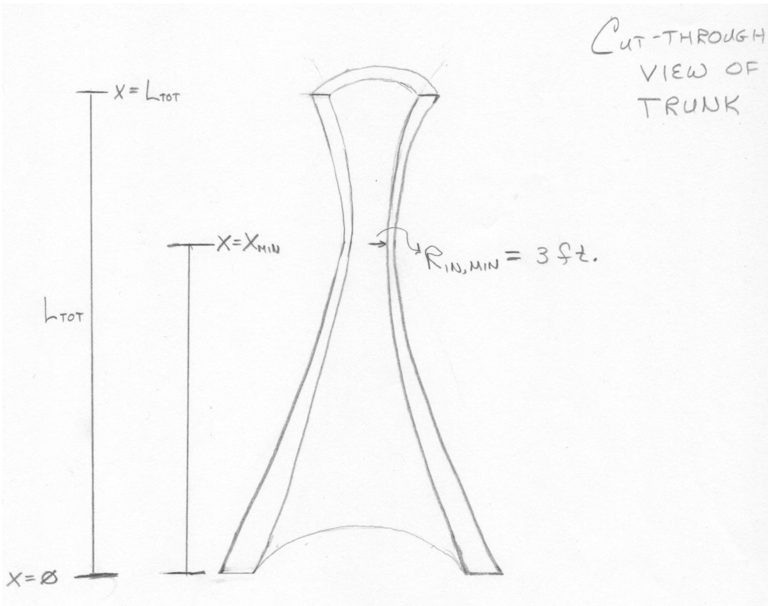
In addition to the external loads on the trunk due to the house levels, you will see below that I desire an elevator to be installed inside the trunk. A different friend of mine pointed out that my friends aren't getting any younger and I may want to provide an easy way to get to the highest level. It will be a relatively small elevator so the total load due to it that you should account for in your design is 10 kips; also, that will be applied 2 ft below the top of the trunk.

OK … now here is where I really need your help (and also where I deviated from your suggestions a bit). Because of the elevator, I want a hollow trunk and the minimum interior radius should be 3 ft. I agreed with Doyle's proposal that tapering is more aesthetically pleasing; however, I think I've gone a bit further with my desires. Also, it won't be a façade. I want the trunk to flare in a way like what I show in the sketch below. Please pardon my lack of drawing ability; then again, you are used to Professor Webb's lack thereof so you should not be too shocked over mine! Don't tell him I said that! But, basically, I want the minimum radius for both the inner and outer wall of the trunk to occur at the same position in x and that should be ~65%-75% of the way up the trunk. Also, above that point, it should flare out less (i.e. up to the top) than it does below that point (i.e. down to the ground). My drawing, though, is not really done to scale very well so I think I've exaggerated that flaring – it probably can be less and still look good and be structurally sound. Also, I don't know what the minimum wall thickness should be. I also don't know how that thickness should vary (perhaps not at all – I doubt that, though).

Professor Webb pointed out to me that you can get this sort of shape if you describe both the inner and outer radius of the cross-section with parabolic equations; for example:

$$R_{in}(x) = ax^2 + bx + c$$
$$R_{out}(x) = dx^2 + ex + f$$

If you know the value of, say, R_{in} that you want at three different values of x, then you can fairly easily solve for a, b, and c in the first equation. The same thing is true for R_{out} and d, e, and f in the second equation. So, if you fix that the minimum value of R_{in} is 3 ft and you set the x-coordinate where that occurs (say, 70% of the way up the trunk), then you have one of the needed pairs of x and R_{in} for determining a, b, and c. Then, if you select reasonable values of R_{in} at the top and bottom, you have the two remaining pairs of x and R_{in} that you need to solve for a, b, and c. Do a similar thing for three pairs of x and R_{out} values and you can solve for d, e, and f.



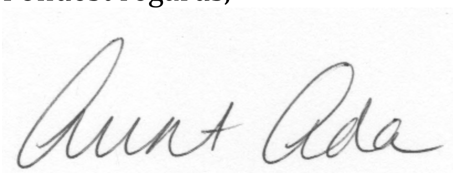
So I would like for you to optimize the cross-section shape and how that varies as a function of x, given the external loads from the house, the elevator, and the weight of the trunk itself. For this grade of steel, the manufacturer has a quoted yield strength of σ_Y = 42 ksi, but don't forget the factor of safety discussed above. Professor Webb has assured me that he will address in lecture how you should estimate a critical buckling load. I would like a trunk design that satisfies the constraints due to both yield and buckling. For yield, this means that nowhere along the length of the trunk should the stress exceed 16.8 ksi ($\sigma(x) < 16.8$ ksi for all x, as that math lovin' Professor of yours would say!). To be optimized, the stress should also not be grossly below this value throughout the length. Again, Professor Webb will instruct you in how to perform your buckling analysis but one thing you will need to carry out that analysis is a highly accurate description of P(x).

As far as how I would like you to document your design and related stress analysis, Professor Webb will convey that to you in a separate document. For now, you know that you need to create an analysis tool that will allow you to compute – with high accuracy – both the stress and the internal load as a function of x. So you'll need to create a 1D finite element analysis code that addresses a hollow circular cross-section "rod" with varying inner and outer radius. It has to account for loading due to the tree house levels, the elevator, and the weight of the trunk itself.

If you have questions, Professor Webb has also assured me that he will answer questions on my behalf and he will do so as completely as he can. He will make suggestions, help you decipher his posted flow chart for a 1D FEA code, help you with errors along the way, and spend some time in lecture discussing this exercise. So I do hope you will enjoy this exercise and help me create a trunk I feel safe in and I also feel aesthetically pleased with.

Thank you in advance and best of luck!

Fondest regards,



Aunt Ada

Dear Team 13,

So sorry to sound informal with that team name – that's Professor Webb's doing, not mine! I wanted to tell you first hand how delighted I was with your recent proposal for the tree trunk to support my "epic tree house". It has been a joy to me to know that my favorite offspring of my dear brother is engaged in engineering pursuits and that you were excited to help out with the trunk design. I am also happy to hear that you assembled a team of other engineering students to help you in this activity; more brains are better, I've often found.

Anyway, I am hoping herein to describe my final design decisions, many of which are based on the suggestions made by your team. For some details, I used inspiration from your proposal but made changes to better suit my desires. I'm hoping that, with what is described below, you will know very specifically the total length of the trunk I desire as well as the material to use throughout the design. I believe that Professor Webb would call these things L_{tot} and E(x). I also describe the levels of the tree house I want to mount to the trunk and where I would like them to go; thus, I am hoping you can turn that into specific information about the external loads on the trunk due to the house. Professor Webb would point out that these are contributions to the overall P(x). Given that information, I am asking your team to optimize the cross-section of the trunk in a manner that I describe further below. So I am asking you to optimize A(x). To repeat, I provide below some specifics about the cross-section I desire and I even put on my engineer's hat to suggest a way for you to constrain your optimization exercise (i.e. to make it more tractable). Please read what I provide below and formulate questions your team has – Professor Webb intends to discuss this activity extensively with you so your questions will be answered as fully as possible.

First, after perusing your suggested trunk heights, I would like the total height to be 110 ft – just a bit above what you suggested. I really like Douglas' and Stephen's suggestions of steel so we will use a 300 series, corrosion-resistant steel throughout; as Professor Webb would point out, for your purposes, that means E(x) = 29×10^6 psi for all values of x. He is a stuffy one, isn't he?! I did like Ryan's suggestion for reinforced concrete but it turns out I have a connection to very high quality steel and an outstanding steel working team. In addition, we are very lucky to be working with a master artist/designer who will create for us a faux bark to be mounted on the steel trunk. He's designing branches, faux leaves – his work is stunning and this is going to look great. However, you don't need to worry about that part, except to know that this thing will not look completely out of place among the pines and firs up here! The weight added by those aesthetic details will be relatively small so we will ignore it, except for the fact that we will use a factor of safety of 2.5 on the yield stress and critical buckling load. More on that below.

Now, about those suggested house designs: great work! I hate to choose favorites among your designs but I was inspired by Douglas' suggestion to have multiple levels. That said, I like the idea as well (and as advanced by Stephen) to have some structure at the very top of the tree. I must confess that I now desire a larger total square footage than I originally imagined. An old friend of mine pointed out that, to host the sort of parties I am known for, I will want more space. Your proposals inspired me to spread that space out among multiple levels, existing at different heights above the forest floor! Absolutely charming suggestions, really. So here's what I'm thinking: please plan for a large, two-story structure down relatively low, with ~4000 ft^2, an intermediate single-story level of ~1500 ft^2, and a large two-story level whose top coincides with the top of the trunk; that last level should be ~3500 ft^2. I would like 10-foot tall ceilings so you should plan for each story to be of sufficient height to accommodate this. The two-story levels should be two times whatever height you determine for each story, of course! When you calculate the total force applied on the trunk by each level, you should then divide that among 3 mount points for the single story level and among 5 mount points for the two-story levels. Our consulting structural engineer has said you should evenly distribute the mount points along the length of the trunk occupied by the given level.

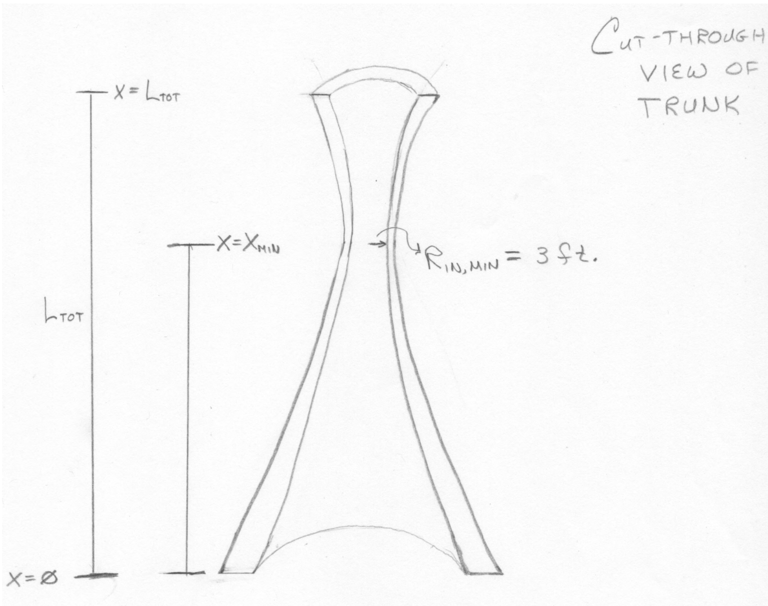
In addition to the external loads on the trunk due to the house levels, you will see below that I desire an elevator to be installed inside the trunk. Thanks very much to your team for helping me realize this! In addition to your suggestions, a different friend of mine pointed out that my friends aren't getting any younger and I may want to provide an easy way to get to the highest level. It will be a relatively small elevator so the total load due to it that you should account for in your design is 10 kips; also, that will be applied 2 ft below the top of the trunk.

OK … now here is where I really need your help. I really loved your ideas of using a hollow trunk with tapering. So, because of the elevator, I want a hollow trunk and the minimum interior radius should be 3 ft. However, here I went a bit "off the rails" in my profile desires! I want the trunk to flare in a way like what I show in the sketch below. Please pardon my lack of drawing ability; then again, you are used to Professor Webb's lack thereof so you should not be too shocked over mine! Don't tell him I said that! But, basically, I want the minimum radius for both the inner and outer wall of the trunk to occur at the same position in x and that should be ~65%-75% of the way up the trunk. Also, above that point, it should flare out less (i.e. up to the top) than it does below that point (i.e. down to the ground). My drawing, though, is not really done to scale very well so I think I've exaggerated that flaring – it probably can be less and still look good and be structurally sound. Also, I don't know what the minimum wall thickness should be. I also don't know how that thickness should vary (perhaps not at all – I doubt that, though).

Professor Webb pointed out to me that you can get this sort of shape if you describe both the inner and outer radius of the cross-section with parabolic equations; for example:

$$R_{in}(x) = ax^2 + bx + c$$
$$R_{out}(x) = dx^2 + ex + f$$

If you know the value of, say, R_{in} that you want at three different values of x, then you can fairly easily solve for a, b, and c in the first equation. The same thing is true for R_{out} and d, e, and f in the second equation. So, if you fix that the minimum value of R_{in} is 3 ft and you set the x-coordinate where that occurs (say, 70% of the way up the trunk), then you have one of the needed pairs of x and R_{in} for determining a, b, and c. Then, if you select reasonable values of R_{in} at the top and bottom, you have the two remaining pairs of x and R_{in} that you need to solve for a, b, and c. Do a similar thing for three pairs of x and R_{out} values and you can solve for d, e, and f.



So I would like for you to optimize the cross-section shape and how that varies as a function of x, given the external loads from the house, the elevator, and the weight of the trunk itself. For this grade of steel, the manufacturer has a quoted yield strength of σ_Y = 42 ksi, but don't forget the factor of safety discussed above. Professor Webb has assured me that he will address in lecture how you should estimate a critical buckling load. I would like a trunk design that satisfies the constraints due to both yield and buckling. For yield, this means that nowhere along the length of the trunk should the stress exceed 16.8 ksi ($\sigma(x) < 16.8$ ksi for all x). To be optimized, the stress should also not be grossly below this value throughout the length. Again, Professor Webb will instruct you in how to perform your buckling analysis but one thing you will need to carry out that analysis is a highly accurate description of P(x).

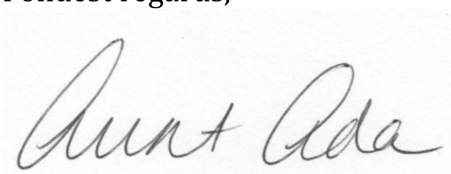
As far as how I would like you to document your design and related stress analysis, Professor Webb will convey that to you in a separate document. For now, you know that you need to create an analysis tool that will allow you to compute – with high accuracy – both the stress and the internal load as a function of x. So you'll need to create a 1D finite element analysis code that addresses a hollow circular cross-section "rod" with varying inner and outer radius. It has to account for loading due to the tree house levels, the elevator, and the weight of the trunk itself.

If you have questions, Professor Webb has also assured me that he will answer questions on my behalf and he will do so as completely as he can. He will make suggestions, help you decipher his posted flow chart for a 1D FEA code, help you with errors along the way, and spend some time in lecture discussing this exercise.

So I do hope you will enjoy this exercise and help me create a trunk I feel safe in and I also feel aesthetically pleased with.

Thank you in advance and best of luck!

Fondest regards,



Aunt Ada

Mech 12 Computational Project #1e, Fall 2015

(Due October 30, 2015 – 100 pts)

Well, I'm sure it is obvious by now that part 1e of the project is a team-based activity!

Herein, I will try to describe to you what is needed from your team to wrap up the trunk design and optimization project. Aunt Ada has provided for each team design specifications that can be converted into L_{tot}, E(x), P(x), and A(x) for a 1D finite element analysis. She simplified things and went with a single construction material; thus, E(x) is constant. Because part of P(x) comes from the weight of the structure, A(x) and P(x) are related and their relationship will be coded into your computational stress analysis tool (i.e. your 1D finite element code). Using L_{tot} and the information provided about loading, you can determine a minimum number of nodes needed to carry out a 1D analysis, as well as where those nodes should be located. Including increasingly more nodes at locations in-between the locations of the minimum required nodes represents mesh refinement. Fun! With P(x) and the nodal locations defined, you can populate all the nodal forces. With E(x), A(x) and all the nodal locations, you can come up with all the element stiffness values. You know how to build your global K. Then solve for displacements, stresses, etc. I'll help … honest! But you have to develop questions and drive the conversation!

So, what do you need to turn in? Each team must submit a stress analysis and design optimization final report for Aunt Ada to read and evaluate. In the report, your team must address the following topics:

- Explain to Aunt Ada the model and optimization parameters (she was fairly specific but not entirely … if you have 4000 ft^2 over two stories, how is the square footage distributed?).
- Verify for Aunt Ada that your final design is indeed safe based on her requests.
- Verify for Aunt Ada that your final design is also optimized (you may use similar material for this bullet as you used in the preceding bullet).
- Wow Aunt Ada with any design benefits that you want to call out (did you deviate from her specs … if so, why); impress her with added insight about your design and its implicit broader thinking.

In addition, each team will be required to submit their computational tool to a dropbox on our Course Site. If it is not obvious how to "run" a team's code, detailed instructions for doing so should also be uploaded.

There is no limit on the number of figures you include in your report and words on figures and in figure captions will not count toward the prescribed word total. Text in the body of the report should be no more than 1100 words. Proposal reports outside the prescribed word count will have points deducted. ***All team members will share the same grade on the response.***

Rubric for student outcome 1e: Finalized Computational Tool and Design Report

	Performance Indicators	Below standard	Meets standard	Above standard	Exemplary performance
1	Functionality of computational tool	Code fails to run or run correctly; it either does not compile or has runtime errors.	Code runs and shows correct logic for 1D FEM. Stress and buckling analysis are present. Runtime errors may occur.	Code compiles and runs properly, providing reasonable results. Analysis of stresses, buckling, and cost may be absent.	Code compiles and runs properly; results are feasible. Analysis of other important factors such as stresses, buckling and cost are present with supporting figures.
2	Safety of Structure	Report does not discuss factors relevant to determining safety.	Report discusses relevant factors to determining safety with supporting arguments from computational analysis. Structure may not meet all requirements.	Report displays figures and discusses data demonstrating necessary factors to determine safety. Structure may not meet all requirements.	Report displays figures and discusses data proving safety of structure. Results are analyzed and explained with regard to relevant points in the structure.
3	Design Justification & Optimization	Report does not provide evidence supporting design choices.	Report provides evidence supporting design choices; shows some evidence of optimizing.	Report supports design choices and optimization is present. Both design choices and optimization process are discussed.	Report discusses and explains all design choices. Optimization is evident with figures and/or data demonstrating the extent of optimization.
4	Report Presentation / Coherence	Report does not follow a structured format; different sections are disjointed.	Report shows evidence of structure. Different sections are well explained but not related fluidly. Facts and figures may not be explained or annotated.	Report structure is well defined and provides a clear structure definition. Sections transition from one into the next. Facts and figures are annotated or explained.	Report structure is evident and sections are all easily related. Structure description is comprehensive and all facts and figures are thoroughly explained and related to the structure.
5	Representation in Society (Curiosity & Project Engagement)	Little to no regard to factors outside of basic mechanical needs are considered.	Due consideration has been given to mechanically relevant factors and client elements (cost, aesthetic).	Provides evidence of interest in the impact of structure on its surroundings and client considerations; expresses this through mechanical considerations.	Evidence of interest in the modularity of the structure, client needs, and impact on surroundings. The overall effect of the structure on society is considered and is connected to mechanical needs.

Mech 12 Class,

To receive your grade on the final part of project 1 (i.e. project 1e), please reply to this email and provide a brief team evaluation below, as follows. You should list each person on your team (including yourself) and assign each person two grades on a scale of zero (0) to four (4). Zero means the person, in your opinion, did very little to nothing whereas a four means the person contributed in an exemplary fashion. Basically, think about it as a letter grade where zero is failing and four is an A. The first grade you should assign is for the numerical/computational analysis of project 1e and the second is for the report for project 1e. It is fine if one student contributed, say, little to the computational analysis but did a highly significant amount of the report writing; in such a case, that student might get a "1" and a "4" and that is fine. That tells me how your team divided labor, etc. Lastly, after you assign your team member grades *including yourself*, please provide any comments you would like but focus on the teamwork aspect for now. From your comments, I'm particularly interested to hear cases where the team worked well together and wants to continue as a team. On the other hand, if there were issues, please let me know in your comments. Note that you will have a separate opportunity to critique the project itself - this is really about teamwork.

Thanks,

EBW

Edmund B. Webb III, Associate Professor
Lehigh University
Mechanical Engineering & Mechanics

Qui docet discit.

Remember Aunt Ada and her Epic Tree House?! The overarching goal of Project 1 was to have students explore the use of computational stress analysis, specifically finite element analysis, in ensuring the integrity of a structural design. However, there was a separate goal in this project.

Professor Webb is exploring the notion of incorporating **entrepreneurial-minded learning** into courses taught under the mechanical engineering curriculum. What is entrepreneurial-minded learning? Well, quite honestly, while we have good notions of what that means, it also remains somewhat open to interpretation. Lehigh University is fortunate to have been invited to join a collection of ~25 universities dedicated to defining what entrepreneurial-minded learning means and using it to transform undergraduate engineering education. Our goal is to drastically improve engineering curricula to manifest students who approach every problem they encounter with a toolkit that encompasses not only well-retained core technical skills but also an absolute dedication to the advancement of humankind. You should realize what being an undergraduate engineering student at this institution means about you: you simply would not be here if you were not a person with the potential to become a world-class engineer who advances transformative solutions to society's problems. You honestly have the potential to – dare I say it – change the world!

So now I need your help.

The cadre of educational institutions that Lehigh was invited to join is known as KEEN – the Kern Entrepreneurial Engineering Network. You can easily find your way to KEEN's website and learn more about their goals and philosophy. To very briefly summarize, KEEN has established what it believes to be the three basic tenets of entrepreneurial-minded learning and they are the three Cs:

Curiosity – all engineers should be curious about our changing world and we seek to foster this curiosity; however, we also want to help you become an engineer who explores contrarian views of accepted solutions.

Connections – we want to help students understand how to integrate information from many sources to gain deeper insight; intrinsic to this, we hope to educate engineers who expertly assess and manage risk since risk often manifests as a result of unexpected connections.

Creating Value – if you have the ability to identify unexpected opportunities to create extraordinary value we know, with near certainty, that you will lead a fruitful and deeply satisfying life. To do this, you must develop an ability to persist through – indeed to learn from – failure and its associated consequences.

Considering these three Cs, I would really appreciate if you would tell me how effective was Project 1 in achieving the educational goals I describe above. ***To complete this part of the Project 1 review, you should send me an email with your thoughts. In doing so, please tell me any ideas you have for making the project (and the class in general) more successful at instilling notions of the three Cs. In your opinion, what educational techniques have the greatest potential to create engineers who, through a vigilant demand to see how their educational preparation and their future work connect to the bigger picture, truly change the world.***

The second part of the Project 1 review is a bit more like what you've seen in the past! Please fill this out and bring it with you to the final exam. ***Please put your name at the top!***

How helpful was each of the following to the development of your computational tool and final report?

1a – Design Consideration Brainstorm

Not Helpful	1	2	3	4	5	Very Helpful

1b – Most Important Criteria (Team Report)

	1	2	3	4	5	

1c – Pseudo Code / Algorithm

	1	2	3	4	5	

1d – Design Proposals (Team Report/Designs)

	1	2	3	4	5	

Did you think "Aunt Ada" gave too much or too little direction during Project 1?

Too Little	1	2	3	4	5	Too Much

Did the use of a "client" help you engage in Project 1?

Not at All	1	2	3	4	5	Definitely!

Did you find the scenario to be a useful and illustrative application of 1D FEA?

Not at All	1	2	3	4	5	Very Useful

Is there anything you would add or remove from the project and, if so, what?

____

____

____

Any other comments or suggestions for Project 1 or projects in the course, in general?

____

____

____