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THE GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

DESIGN QUALIFIER

FALL 2008

WRITTEN EXAMINATION

We are interested in learning what you know and your ability to reason in the formulation and solution of design problems.

If you find any question or part of this exam confusing, please state your assumptions and rephrase the question and proceed.

Please read the entire exam first.

Questions 1 and 2 carry equal points. Both have multiple parts.

An equation sheet is not available for this examination. Students should be familiar with the equations required.

Allocate your time carefully so that you cover all three parts that you are being examined on in these two questions, namely Methods, Realizability and Analysis.

ORAL EXAMINATION

Please arrive a half an hour before the scheduled time for the oral exam. During this period we will give you a question to think about. The scope of the oral exam is as follows:

* provide an opportunity for you to state how design fits into your research activities;
* probe your understanding on the question that we posed to you in the preceding half hour.

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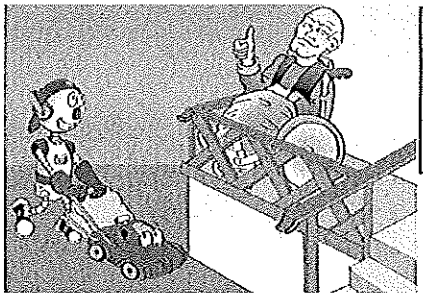
QUESTION 1- METHOD AND REALIZABILITY



Robotic Lawn Mowers On The Rise

Georgia Tech PhD students are working on a concept for robotic lawn mowers that will revolutionize the market.

THE PROBLEM

For most Georgia residents cutting the lawn in their front or back yard is part of the joys of homeownership. However, for many physically handicapped people or the elderly this can be a tedious task. Similarly, many people who have full time jobs hardly find the time to take care of their yards. One of the current solutions to this problem is to pay someone to perform this task. While this may be feasible in the private sector, for companies or institutions who own large areas of grass land this is a significant cost factor.

ROBOTIC LAWN MOWERS AND CHARGERS

Recently, MagicCut, a local company, has given a $100,000 grant to Georgia Tech for their PhD students to design a product family of robotic lawn mowers for both the private and the industrial sector. The family of robotic lawn mowers to be designed must cover the range from 0.5 acres of land to 10 acres of land. Once started, they should function without any human interaction until the grass in the entire designated area of land has been cut. This may require that the robotic lawn mower automatically restores power (whatever its power source may be) until the job is done. Another requirement the company has stated is that the robotic lawn mower also needs to take care of the clippings. The clippings may either be automatically disposed or used for fertilizer.

Task

Assume that you are in charge of the design student team responsible for developing a robotic lawn mower as outlined above.

- Speculate about the customer requirements to be anticipated for both business and private customers.
- What is the function structure that provides the most flexibility for designing a product family of robotic lawn mowers including power-restoring devices?
- What are the components of such robotic lawn mowers and power-restoring devices?
- How can power be provided and restored?
- How can the clipping disposal or reuse be accomplished?

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Deliverables
Method

1.1 *Clarify the Task:* State the overall function of your system in solution neutral terms. What are the most important drivers/design criteria? Define a design requirements list.

1.2 *Conceptual Design:* State and implement the steps (including functional diagrams/decomposition) for transforming the overall function that you have identified for your product family into at least three alternative design solutions. Ensure that you have identified the important sub functions. Sketch and describe the workings of these alternatives.

1.3 *Selection:* Suggest a structured approach to selecting one of the alternatives for further development.

Realizability

1.4 *Embodiment:* Further develop the alternative that you have selected.
1.5 *Costing:* How would you estimate the cost of your design? You may critically evaluate the design in terms of manufacturability, initial cost, maintenance cost, reliability, manipulation performance, and other criteria that you feel are important to consider in this phase of design.
1.6 *Pricing:* Based on the preceding analysis, how would you estimate the market size for such a system and set the price for selling such a system? Be brief.
1.7 *Return on investment:* In addition to costing and pricing, estimate if purchasing and using a robotic lawn mower would be a viable solution for a customer such as Georgia Tech. How much money could be saved over the course of one year?

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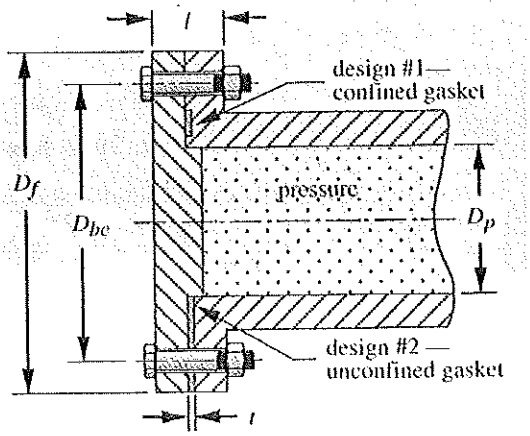
2A



One power source that is being contemplated is compressed air stored in a flanged cylindrical tube (outer diameter = 5.2 inches) sealed off by a lid that is bolted onto the cylinder's flange. In the above figure, a schematic drawing of the tube and its flange and lid is given. The lid is bolted onto the flange.

The pressure in the cylinder is 1500 psi.

Furthermore, the initial design has the dimensions $D_f = 5.8$ inch; $D_{bc} = 5.5$ inch; $D_p = 5$ inch.

As mentioned, the outer diameter of the tube is 5.2 inches.

The clamped length of the joint (l) is 1.5 inch.

Both the lid and pipe are made out of the same material (steel) with modulus of elasticity of 30 MPsi.

The bolts are steel 3/8-16 UNC SAE class 5.2 bolts with tensile stress area of 0.0775 inch^2 and proof strength 85 kpsi.

Modulus of elasticity is also 30 MPsi. The length of the bolt shank is 1 inch.

Assume that only two bolts are used in the assembly and no gaskets are used (contrary to what is shown in the diagram).

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Answer the following questions:

2A.1 Calculate the joint stiffness factor (or bolt constant) C (3 pt)

2A.2 Assuming a bolt constant of 0.35, calculate the minimum pre-load F_i required to avoid joint separation. (2 pt)

2A.3 Assuming a preload of 6000 lbs per bolt, calculate the factor of safety against static bolt failure. (2 pt)

2a.4 Provide several reasons why you would not recommend using the fastener design given here in this description. (2 pt)

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2B. Please write a complete descriptive answer in the space provided.

2B.1. Explain the meaning of L_{10} life. (1 pt.)

2B.2. Explain what happens when the Static Load Rating is exceeded. (1 pt.)

2B.3. Can you use stress-concentration factor with ductile materials when they are subject only to static loads? Explain. (1 pt.)

2B.4. Why are nuts for regular fasteners made of soft material? (1 pt.)

2B.5. Why are washers used in bolted connections? Give two reasons. (1 pt.)

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2B.6. Why is a minimum clash allowance of 10-15% recommended for a compression spring? (1 pt.)

2B.7. How can you avoid the adverse effect of spring surge? (1 pt.)

2B.8. What is the property of the Angular Velocity Ratio (m_v) between gears in a gear set? (1 pt.)

2B.9. Why is it desirable to have Contact Ratio, $m_p > 1$? (1 pt.)

2B.10. Why is Backlash undesirable? (1 pt.)