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

DESIGN QUALIFIER

FALL 2013

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 part of this exam confusing, please state your assumptions and rephrase the question and proceed.

Please read the entire exam first.

Questions I, IIA and IIB carry equal points.

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

ORAL EXAMINATION

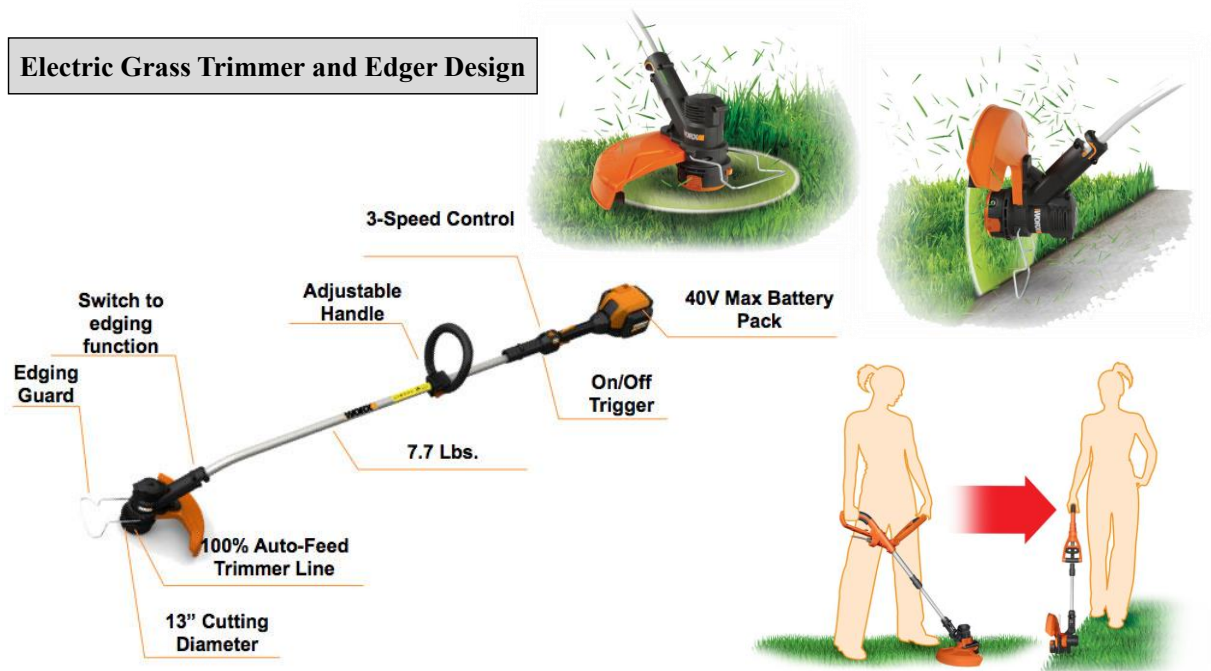
Please arrive a half an hour before the scheduled time for the oral exam. During this period we will give you a question to think about. The scope of the oral exam is as follows:

- * 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.

QUESTION I. – DESIGN METHODOLOGY

DESIGN PROBLEM

A grass trimmer and edger is a lawn maintenance tool that enables the trimming and edging functions to be integrated in one product structure. Market studies have revealed a number of trends. Not causing any pollution, a battery powered trimmer/edger has a number of advantages over gas-powered units. An electric/battery-powered trimmer/edger unit is lighter, quieter and vibrates less. An electric motor drives the trimmer line, so there is no need to mix fuel or refill. It is also possible to design a trimmer and edger with variable speed adjustment for superior control. In addition to efficient battery power, it is important to be designed for maximal comfort and ease of use.



TASK

Assume that you are in charge of a design team responsible for developing a new electric/battery-powered trimmer/edger for your company. Your boss wants you to start from benchmarking with your competitors and to document your design process thoroughly. You are advised to follow the general guidelines of a systematic design methodology and turn in a report documenting the main deliverables as follows.

DELIVERABLES (YOU ARE REQUIRED TO ELABORATED THESE ISSUES)

- 1.1 *Requirement Analysis:* To clarify the design task, you need to identify the customer needs to be met by your design. Develop a list of functional requirements for your design in solution neutral terms. Prioritize the importance of design criteria? **(2 pt.)**
- 1.2 *Conceptual Design:* Compose appropriate function structure diagrams that characterize the overall function and its decomposition into sub-functions. Transform the function structure into working principles of your design solution(s) to the module levels. **(2 pt.)**

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- 1.3 *Design Evaluation*: Formulate a structured, systematic procedure for evaluating your design concept(s). Hint: You may use one of the formal methods (No intuition-based approach please, e.g., evaluating by subjective scores), such as Pugh Selection Matrix, QFD, or multi-attribute decision making, etc. **(2 pt.)**
- 1.4 *Embodiment*: What are the major issues that you should deal with at the embodiment design stage? Outline what types of engineering analysis that may be needed in order to justify the technical feasibility of your design. **(1 pt.)**
- 1.5 *Product Costing*: How would you estimate the cost of your design? Please outline a systematic procedure. If considering mass production of your design, what are the critical issues for managing product cost of your design? **(2 pt.)**
- 1.6 *Pricing*: How would you estimate the market size (i.e., product demand) for your product? What are the tradeoffs underlying the pricing decisions for selling your product? **(1 pt.)**

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QUESTION IIA: Figure 1 shows a person using an aerial lift to work on a building in Atlantic Station. The machine uses a telescoping boom to lift up the operator and tools. The boom arm rotates from horizontal to a nearly vertical direction on a bearing at its base. This rotation is powered by the hydraulic piston shown in Figure 2. The piston is mounted on its own bearing at a horizontal distance of 1m from the boom bearing. The other end of the piston is mounted 3m up the boom. The boom arm weights approximately 80 kg/m.

1) Assume the boom is at its maximum extended length of 30m and the combined weight of the workers, tools, and passenger basket is 300 kg. Further assume that this weight is supported directly at the end of the boom (not offset to the right as shown in Figure 1). What force must the piston exert to hold the boom at an angle of 20 degrees relative to vertical? **(2 pts.)**

2) Using your answer to part 1, calculate the forces that each bearing (boom and piston) must support. Give the forces in terms of their vertical and horizontal components. **(2 pts.)**

3) What type of bearings do you recommend for this application? Sketch how they would be connected to the machine. **(2 pts.)**

4) Assume the boom is a uniform circular hollow tube. Where is the maximum shear stress located? How would you redesign the boom (change it from a uniform hollow tube) to decrease the shear stress? **(2 pts.)**

5) Assume that the tires on the right side compress 2cm under the above conditions. What else would you need to know to calculate their stiffness? How would you use the information? **(2 pts.)**



Figure 1: Aerial Lift.



Figure 2: Hydraulic Piston.

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QUESTIONS IIB. Please write a complete descriptive answer in the space provided.

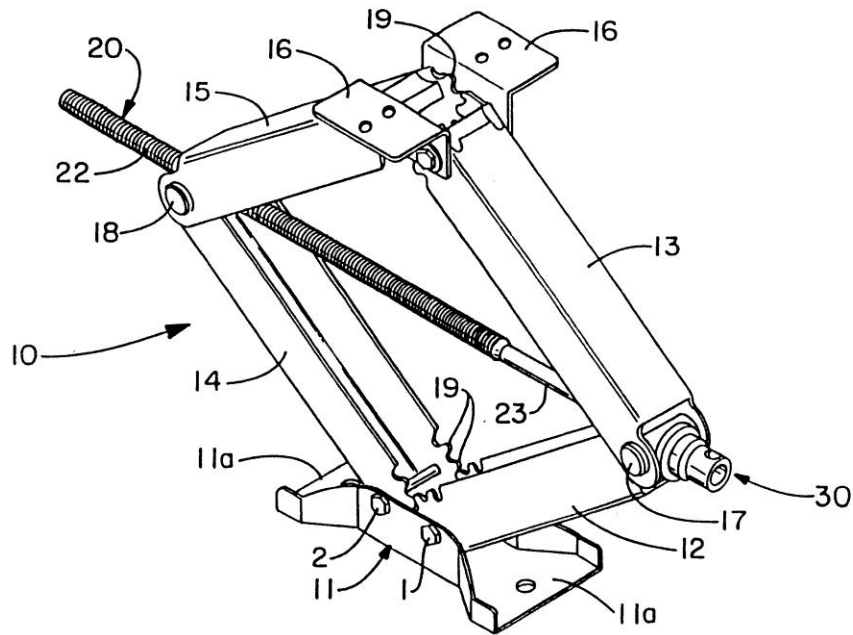


Figure 1 – Automobile Scissor Jack

II B.1. In Figure 1, an automobile scissor jack is shown. Referring to Figure 1, describe the most likely failure points and explain your reasoning. **(1 pt.)**

II B.2. In addition to being a power screw, what is the most important condition with respect to thread design that an automotive scissor jack (like shown in Figure 1) relies upon in its working? **(1 pt.)**

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II B.3. Describe two ways to manufacture screw threads and discuss the pros and cons of each with respect to the performance of the threads ? (1 pt.)

II B.4. Why are springs not made from cast iron ("not strong enough" is not a reason)? (1 pt.)

II B.5. Can a worm gear drive a worm? Why or why not? (1 pt.)

II B.6. Why are bevel gears in general not interchangeable? (1 pt.)

II B.7. Why do you typically need at least one "floating" bearing in a shaft assembly supported by two bearings? (1 pt.)

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II B.8. Why is a leaf spring preferred over a helical compression spring in the rear suspension of a truck shown in Figure 2 (1 pt.)

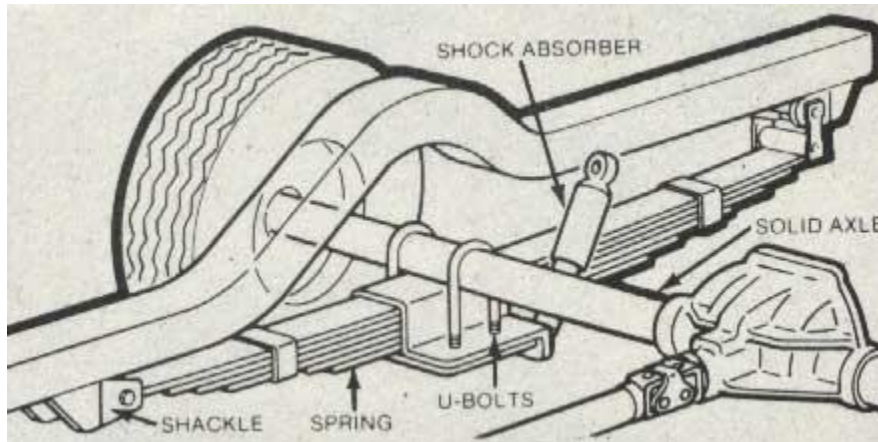


Figure 2 – Truck rear suspension

II B.9. What is fretting and how can it be avoided? (1 pt.)

II B.10. Why are contact ratios greater than one preferred in gear systems? (1 pt.)