ID Number ________________________

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

DESIGN QUALIFIER

SPRING 2009

WRITTEN EXAMINATION

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

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

<u>Please read the entire exam first.</u>

<u>Questions 1 and 2 carry equal points. Both have multiple parts.</u>

<u>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.</u>

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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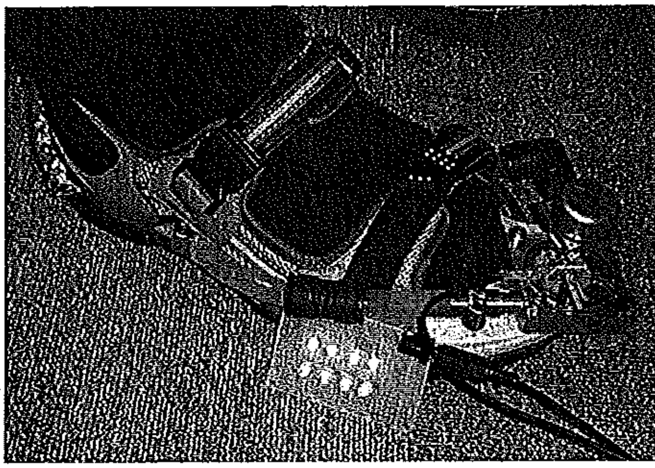
QUESTION 1- METHOD AND REALIZABILITY



Hydroelectric Footwear for all Georgia Tech Students

Georgia Tech PhD students are looking into concepts for shoes that produce energy while you walk.

BACKGROUND AND MOTIVATION

For the past couple of years most Georgia Tech students have been wearing flip-flops or sneakers as their main choice of footwear throughout the entire year. In addition, most students are carrying around several types of gadgets (e.g., cell phones, iPods, calculators, laptops, etc.) every day. Due to the current economic crisis, the Georgia Tech Leadership team has agreed on a stimulus package through which all Georgia Tech students will be provided with hydroelectric footwear effective fall semester 2009. That way, just by walking across campus students can produce enough electricity to power their gadgets and thus decrease their electricity bills and finally have same extra bucks to spend on a frat party.

HYDROELECTRIC FOOTWEAR

Recently, MagicFeet, a local company, has given a $100,000 grant to Georgia Tech for their PhD students to design a product family of hydroelectric footwear (flip-flops and sneakers) for all common sizes. Shoes for experimentation will be provided by local companies. The family of hydroelectric footwear products to be designed must offer models that produce enough power to operate a cell phone, iPod, calculator or even a laptop. An additional problem is that there has to be a way to store the electricity produced while walking, so that the electronic devices to be driven can be used on the go, in class, or while chilling.

Task

Assume that you are in charge of the design student team responsible for developing hydroelectric footwear as outlined above.

- Identify the customer requirements to be met by your design.
- What is the underlying working principle to realize this type of product?
- What is the function structure that provides the most flexibility for designing product families of hydroelectric flip-flops and sneakers for the above mentioned purposes?
- What are the components of such hydroelectric shoe kits and electricity-storing devices?
- How can generated electricity be stored and/or fed into a grid?

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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 an appropriate number of 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 hydroelectric footwear would be a viable solution for a student customer. How much money could be saved over the course of one year?

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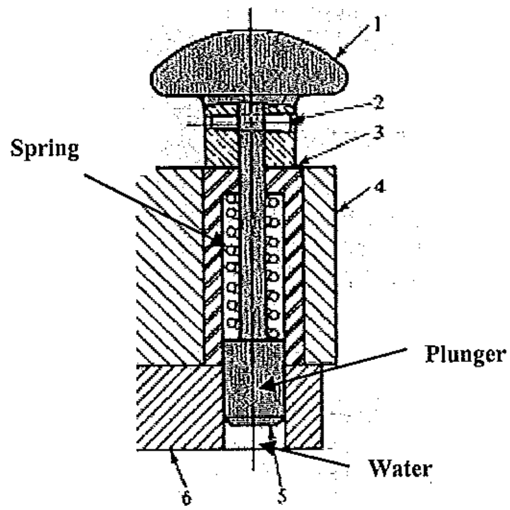
Question II A
Component Design Analysis

Below you see the spring return system that returns a hydro plunger back to its original position. The water pressure moves the plunger upward during a step. The helical compression spring ensures that the plunger is pushed back into its original position. The plunger diameter is 5 mm. The spring has squared and ground ends



The spring has 12 total coils with plain ends. The wire diameter of the spring is 0.75 mm, the mean coil diameter is 4 mm . The spring material is A228 music wire with a modulus of rigidity G = 79.3 GPa and Modulus of Elasticity E = 206.8 GPa.

Useful equation: $k = d^4 G / (8D^3 N_a)$

a) Calculate the solid length of the spring

b) Calculate the displacement of the spring if the water pressure is 0.4 N/mm^2

c) Will the spring buckle? Explain your answer.

d) Provide recommendations for a redesign of the spring that gives greater travel of the plunger

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

II B.1. Under what loading conditions would it be advantageous to use the following thread types?

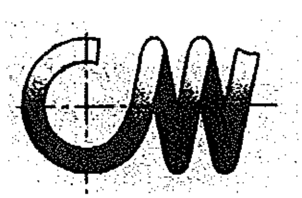
II B.1a. Square: **(0.5pt.)**

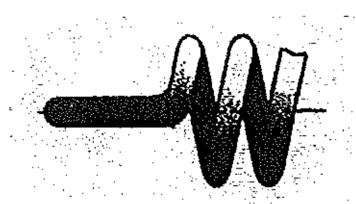
II B.1b. ACME: **(0.5 pt)**

II B.2. As a mechanical designer, which of these loading conditions would you prefer and why: a load applied gradually or an equal load applied suddenly on a machine part? **(1 pt.)**

II B.3. What is the relationship between stress concentration factor, K_t, and fatigue factor, K_f, at 1000 cycles? Explain your answer. **(1.0 pt.)**

II B.4. In the drawings below, label (indicate) the points where maximum bending stress and maximum torsional stresses occur. **(1. pt.)**





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II B.5. Explain what happens when the Static Load Rating is exceeded. **(1 pt.)**

II B.6. When a torsion spring is loaded to close the coil, the coil ____________ decreases and its ____________ increases as the coil is "wound up". **(1 pt.)**

II B.7. Give two reasons why round wire is mostly used for making springs. **(1 pt.)**

II B.8. Discuss the differences between confined and unconfined gaskets **(1.0 pt.)**

II B.9. List two reasons why we use gears **(1.0 pt.)**

II B.10. What is the effect of undercutting on gear tooth, and what is its consequence on gears? **(1.0 pt.)**