ID Number ________________________

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

DESIGN QUALIFIER

FALL 2010

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 of 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.

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 I. – METHOD AND REALIZABILITY

Stackable Electric City Car

BACKGROUND AND MOTIVATION

While public transportation is a great green urban option, the "last mile" problem is still a real shortcoming - referring to the conundrum of the extra distance from your bus or train stop to your doorstep. The MIT Media Lab has brainstormed a possible solution to that problem: a stackable (foldable) electric two-passenger city car, as illustrated in the above figures. Such a city car would combine the best features of mass transit, car-sharing, and personal transportation in a high-density, high-convenience system.

DESIGN PROBLEM

The engineering implications of city car design are multifold. Stacks of vehicles could be placed throughout the city to create a small network that is linked to the existing mass transportation systems within the city. When people get off a bus or train, they can just hop into one of these vehicles and go about their business. They can either drop it off at the vehicle stack at their destination, if there happens to be one, or return it to the stack at their origin, where the vehicle will be recharged and wait for the next person to take it. Moreover, the cars are electric vehicles. Rather than using a single engine motor, the cars come equipped with four in-wheel electric motors, powered by lithium-ion batteries. The electric motor and suspension system of the wheel eliminate the need for traditional drive train configurations, like gear boxes, thus no need for a large engine block, and furthermore making the cars smaller and more maneuverable.

TASK

Assume that you are in charge of a design team responsible for developing the above city car. Your boss wants you to start from scratch and document your design process thoroughly, but this is not possible due to lack of time. A senior engineer has suggested that you follow the general guidelines given below and turn in a report documenting each of the sis steps.

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DELIVERABLES

Method

I.1 *Clarify the Task:* Identify the customer requirements to be met by your design. State the overall function of your system in solution neutral terms. Prioritize the importance of drivers/design criteria? Define a design requirement list.

I.2 *Conceptual Design:* What function structure may provide the most flexibility for designing a product platform and product family for the above-mentioned purpose? State and implement the steps (including functional diagrams/decomposition) for transforming the overall function that you have identified for your product family into several alternative design solutions (to the module levels). Ensure that you have identified the important sub functions. Sketch and describe the working principles of these alternatives.

I.3 *Selection:* Formulate a structured systematic procedure (viz., decision model) for evaluating design alternatives and selecting the best one for further development, while considering relative importance of multiple design criteria, along with engineering constraints.

Realizability

I.4 *Embodiment:* Further develop the alternative that you have selected to appropriate abstraction levels. Outline what types of engineering analysis are needed in order to justify the technical feasibility of your design.

I.5 *Costing:* How would you estimate the cost of your design (i.e., product costing)? You may critically evaluate the design in terms of manufacturability, initial cost, maintenance cost, reliability, manipulation performance, energy consumption, return on investment, and other criteria that you think important to consider in this phase of design. If considering mass production of your design, what are the critical issues for managing product cost of your design?

I.6 *Pricing:* The city car concept essentially entails a product-service system that delivers customized service as a bundle of product and service components. Considering such a business model, how would you estimate the market size (i.e., product demand) for such a product? What are the tradeoffs underlying the pricing decisions for selling or operating such a system?

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QUESTION II.A. – COMPONENT DESIGN ANALYSES

Short Answer. Please write a complete descriptive answer in the space provided.

1 During cyclic stress repetitions, (a) what type of material will increase its strength? (b) What type of material will decrease its strength? (c) Explain the meaning of Marin factors **(1.5 pts.)**

2 List two advantages of Shot Peening. **(1 pt.)**

3 How does curvature of a spring affect stresses on the inside and outside of the spring? **(1 pt.)**

4 Is buckling an issue with an extension spring? Explain **(1 pt.)**

5 During fatigue conditions in bearings, failure occurs with separation of scale-like particles from surface called ________________________? **(0.5 pt.)**

6 What is the other important function of lubrication (such as oil) other than reducing friction in bearings? **(0.5 pt.)**

7 Explain the meaning of, (a) bolt lead (l) and (b) thread pitch (p). (c) In a 3-start thread, the bolt lead (l) is equal to what? (d) Why do designers use multiple threads? **(2.0 pts.)**

8 Spur gears are used in race car transmissions because they are quieter: **true or false: ______________?** If false, then why are they used in race cars? **(1 pt.)**

9 Name two profiles that can produce conjugate actions. **(1.0 pt.)**

10 What is a Pressure Line (Line of Action)? **(0.5 pt.)**

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QUESTION II.B.

1. Consider a helical compression spring with the following information (not all are necessarily needed):

Ends: Squared and ground
Spring is not preset
Material: Music wire (steel) with S_{ut}=283 ksi
d=.055 inches and D=0.48 inches
L_f=1.36 inches and N_t=10

Find the following:

a) Spring constant, K (3 points)
b) Length at minimum working load of 5 lbs (1 point)
c) Length at maximum load of 10 lbs (1 point)
d) Solid length (1 point)
e) Load corresponding to solid length (1 point)
f) Clash allowance (1 point)
g) Shear stress at solid length (2 point)

2. Assuming that the total load on a ball bearing use in this gear system is 10000 N and the bearing's basic load rating is 30000 N, what is the L_{10} life of the bearing? What would the L_{10} life be is a roller bearing was used with the same basic load rating and the same load conditions? Is either life sufficient for an automobile clutch (why/why not)? (3 points)

3. In the Figure below, an epicyclical (or planetary) gear system is given.

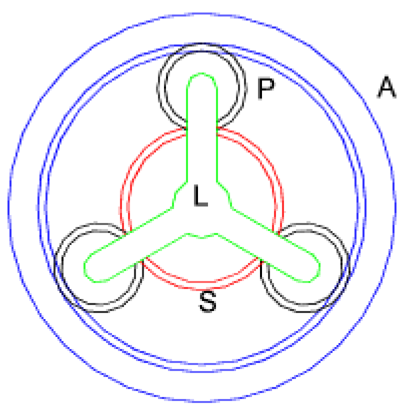

Figure - Epicyclical Gear System (not drawn to scale)

How many teeth (ZS) has the sun gear S of the gear system in Figure 2, if the number of teeth on gear wheel A (internal ring), ZA = 70, and the number of teeth on gear wheel P (planet wheel), ZP = 20? Arm L provides input motion and A the output motion. (2 points)