ID Number______________________________________

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

DESIGN QUALIFIER SPRING 2015

PART I. 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.

PART II. 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 – KNEE BRACE

Assume that you are in charge of a design team responsible for developing a concept of a better knee brace that can be worn post-operation, throughout recovery, and during athletic activity. Creating a more comfortable, cost effective, hybridized, and easily customizable knee brace is the main problem. The design should consider material selection and production processes, in addition to the functions.




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:

(a) Develop a list of functional requirements for your design in solution neutral terms; **(1 pt.)**

(b) Prioritize the importance of design criteria. **(1 pt.)**

1.2 *Conceptual Design:*

(a) Compose appropriate function structure diagram that characterize the overall function and its decomposition into sub-functions. You are required to use one of the formal function analysis tools, such as FBS, IDEF0, FAST, UML, and the like. **(1 pt.)**

(b) Transform the function structure into working principles of your design solution(s) to the module levels. Again you are required to use one of the formal design decision making tools, rather than by intuition. State which method you are using. **(1 pt.)**

1.3 *Design Evaluation:*

(a) Formulate a structured, systematic procedure for evaluating your design concept(s). Hint: You may use one of the <u>formal methods</u> (No intuition-based approach please, e.g., evaluating by subjective scores). You could use such formal methods as Pugh Selection Matrix, QFD, or multi-attribute decision making, etc. **(1 pt.)**

(b) How should you model customer preference and incorporate customer preference in design evaluation? **(1 pt.)**

1.4 *Embodiment:*

(a) What are the major design decisions that you should deal with at the embodiment design stage? **(1 pt.)**

(b) Outline what types of engineering analysis that may be needed in order to justify the technical feasibility of your design. Note we are not talking about engineering analysis at the detailed design stage, but the system-level design – embodiment design. **(1 pt.)**

1.5 *Product Costing:*

(a) Use break-even analysis to justify the cost of your design? **(1 pt.)**

(b) In regard to mass production, what are the critical issues for managing product cost of your design? **(1 pt.)**

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IIA. Design Analysis **(10 pts)**

Playpens provide a safe environment for babies to sleep and play, under limited supervision by their parents. Although playpens have existed for probably thousands of years, the design of playpens continues to evolve with changing consumer preferences, material properties, and manufacturing methods.

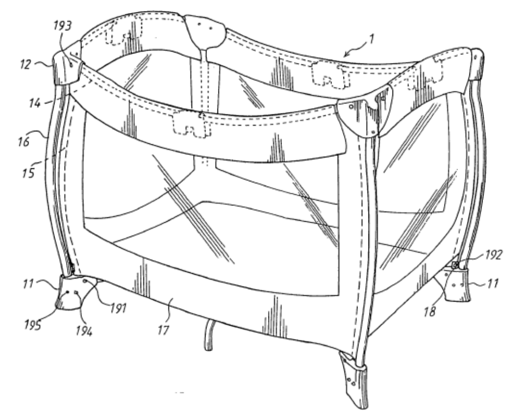

Figure 1: Playpen from US patent 6,954,949.

Figure 1 shows a playpen patented in US 6,954,949. The playpen has curved upright support tubes at each of the four corners. Furthermore, there are two columns (labeled 15 & 16) at each corner, as shown in Figure 2. The fabric sheet that forms the enclosure passes between the two columns. The outer columns support mostly vertical loads, while the inner columns support both vertical loads and lateral loads caused by the fabric pulling sideways.

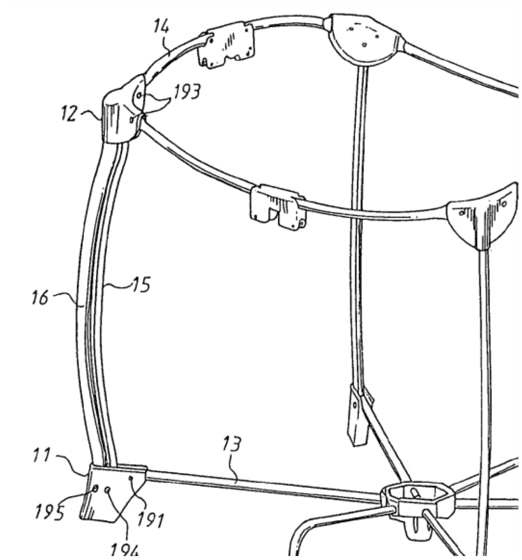

Figure 2: Dual-Column Corner.

a) Ignore the inner column for the first part of this analysis. Assume that the outer column is vertically straight and it must support a load that occurs when the parent leans onto the top horizontal rail to place the baby in the playpen. You can assume the load is 100 lbs and is concentrated in the middle of the top rail (near label 14 in Figure 2.) Also assume that the vertical post is 30 in high and the top horizontal bar is 30 in wide. What is the peak load felt by the vertical tube and where does it occur in the tube? You can use assumed values for any tube properties other than the 30 in height. (3pts).

b) How does bending the tube into a curved shape affect the peak loading conditions? Does it increase or decrease them? Does it shift the position of the peak load?(2 pts)

c) Now consider the effect of the inner tube (15). Assume that it carries ½ of the vertical load from the parent, plus the horizontal load of the fabric pulling sideways. You can assume that the fabric applies a net load of 50 lbs. distributed along the tube and directed toward the center of the playpen. What is the peak load felt by the inner vertical tube and where does it occur in the tube? (4 pts)

d) How does bending the tube affect its loading conditions? (1 pt)

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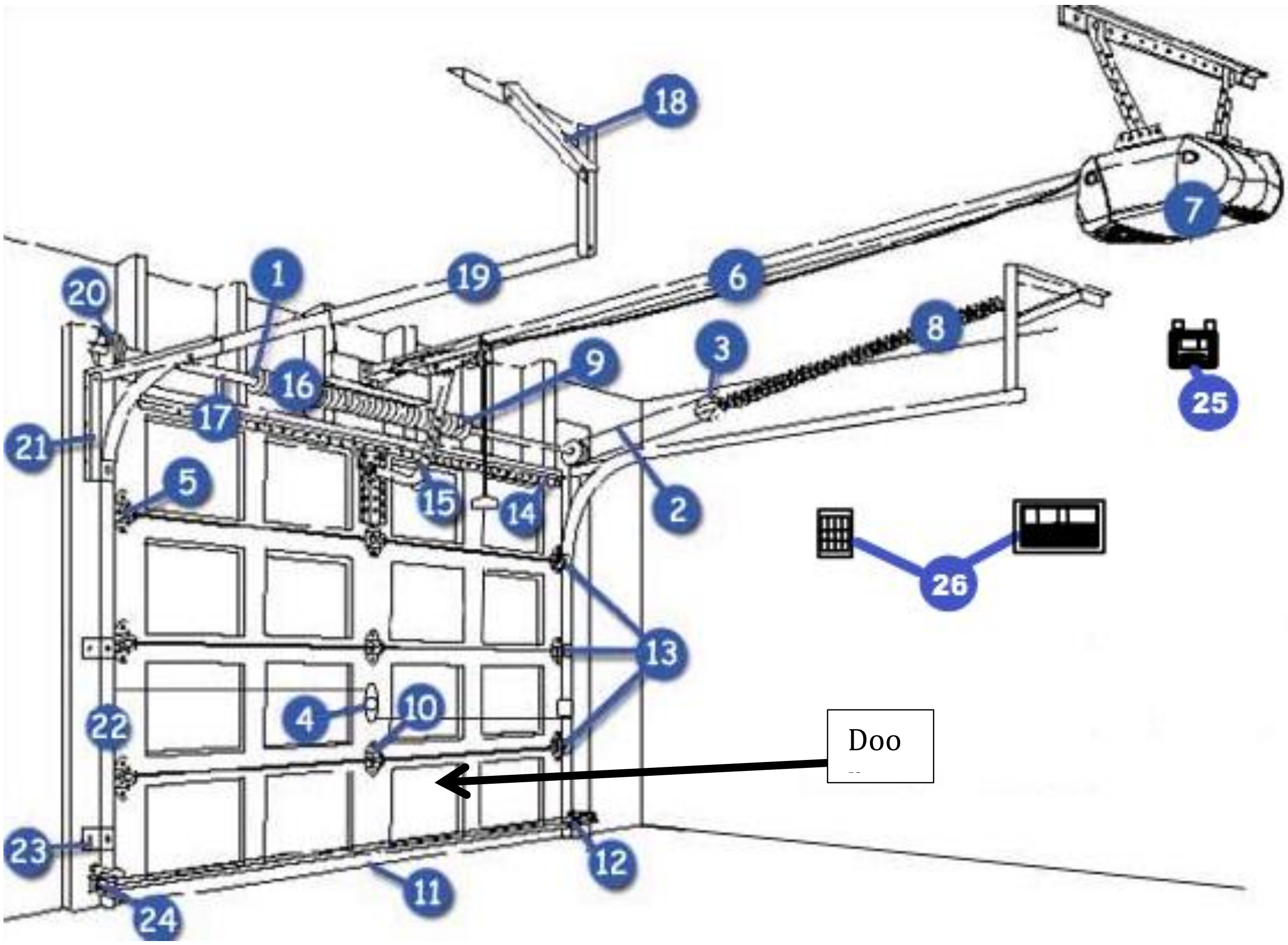
IIB: COMPONENT DESIGN - Short Answer Questions (10 Points)

Please write a complete descriptive answer in the space provided.



1. Bearing Plates	11. Weatherstripping	19. Track
2. Cables	12. Bottom Fixtures	20. Torsion bar shaft bearing
3 Pulleys & Sheaves	13. Graduated Hinges	21. Flag Brackets
4. Locks & Handles	14. Top Fixtures	22. Vertical Tracks
5. Rollers	15. Quick Disconnect Arms	23. Track Brackets
6. Garage Door Rail Components	16. Garage Door Torsion Springs	24. Sensors
7. Garage Door Openers	17. Torsion Spring Shafts	25. Garage Door Remotes
8. Extension Springs	18. Angle Iron Brackets	26. Garage Door Keypads

Figure 1 – Garage Door Opener

In Figure 1, a typical garage door opener found in many US homes is shown. The door is typically made out of wood or steel with insulation. It can be the width of a single car, or two cars, and thus up to 5 meters wide. Obviously, a 5 meter wide door is pretty heavy and needs some mechanical means to be opened. A typical garage door, therefore, has a motor system that opens the door. In Figure 1, the opener (7) contains this motor, which activities a “belt” or chain (6) which pulls the door up. But as you can see in the picture, there are a lot of components to a typical garage door, and the single motor is typically not enough to pull up the door by itself.

1. Referring to Figure 1, name the most critical components with respect to mechanical failure in the design of such a garage door opener and explain your reasoning (3 pt.)

2. Referring to Figure 1, what is the purpose of the torsion springs (16)? (1 pt.)

3. Referring to Figure 1, what is the purpose of the sensor (24)? (1 pt.)

4. Referring to Figure 1, would it be a major or minor issue when the torsion spring (16) would fail? Explain your answer (1 pt.)

5. Referring to Figure 1, would you be worried about the bearings in the rollers (5) or torsion spring shaft (20) wearing out? Explain your answer (1 pt.)

6. Referring to Figure 1, why are angle iron brackets (18) used to connect the track (19) to the ceiling? (1 pt.)

7. The motor in the opener (7) operates a chain along the rail (6). Would you recommend this chain to have a high or low factor of safety? Explain your answer? (1 pt.)

8. What is an S-N curve and what is it used for? (1 pt.)