People with disabilities sometimes have difficulty interacting with others because they are seated below the “normal” interacting standing height. Furthermore, sitting in a wheelchair makes it difficult to reach items on shelves and other high places. Therefore, there is a need for a wheelchair that elevates the user.

Numerous such wheelchairs have been developed, but success has been limited. One of the more exotic elevated wheelchairs is the iBot (a precursor to the Segway) shown in Figure 1. A video demonstrating the iBot can be viewed here: [https://www.youtube.com/watch?v=ITrqcDspEOU](https://www.youtube.com/watch?v=ITrqcDspEOU)

Unfortunately, the iBot is expensive and mechanically unstable – it falls over without active feedback control. This property makes the device dangerous – especially for riders who do not have good jumping, landing, and falling skills. (Note that the owner of the Segway company died when his machine went unstable: [http://www.nytimes.com/2010/09/28/technology/28segway.html](http://www.nytimes.com/2010/09/28/technology/28segway.html))

We can learn a great deal from previously developed products, but a significant engineering breakthrough is needed in the field of elevated wheelchairs.

**Your assignment is to design an Elevated Wheelchair.**

Your design should address several objectives:

1. Safety
2. Cost
3. Compatibility with various environments
4. Legal requirements
5. Robustness to elements (wind, rain)
6. Robustness to terrain
7. Size and weight
8. Ease of use
9. Other qualities that you and your potential customers feel are important

During the early phase of the design process, you should strive to thoroughly understand the customer needs. You should also thoroughly investigate related products and incorporate the best features from them into your design. Each member of the team must create and analyze their own House of Quality for Homework #1 and a specification list for Homework #2. These
related individual assignments can be worked on as a team, but each student must submit their own version and their own written discussion of the House of Quality and specification list.

**Problem Understanding Exercise (Week 1 in Studio)**

Given that you will want to elevate the user as much as possible, your design might start to resemble an *inverted* pendulum. A *standard* pendulum is an inertia suspended from a pivot point that allows it to swing back and forth. As the pendulum swings, gravity drives it back to the equilibrium position of hanging straight down. It is a naturally stable system that is seen throughout the world – in baby swings, cranes, etc.

An inverted pendulum has its mass center above the pivot point, as shown in Figure 2. When the mass leans slightly away from the vertical position, the force of gravity creates a torque that acts to tip the pendulum over further. Perhaps the most useful inverted pendulums are rockets.

![Figure 2: Inverted Pendulum](image)

We can develop an understanding of the balancing problem by trying to build a structure that is as close to an inverted pendulum as possible, while still being stable. Your goal is to build a tower with a narrow base that can support a tennis ball as high as possible. You will build your structures with boxes of spaghetti and rolls of tape.

**In-Class Exercise**

This exercise consists of two parts. First, you will build a tower on top of the spaghetti box when it is laying flat on its long *wide* side. Second, you will build another tower on the spaghetti box when it is laying flat on its long *narrow* side. You are limited to one box of spaghetti and one roll of tape per tower.

The tower can only be attached to the spaghetti box and the box must be resting freely on the table – it cannot be taped to the table, or the ceiling, etc. You will need to attach the tennis ball to your tower using the materials provided. You will be responsible for cleaning up your area, including the removal of all tape.

**Part 1:** You will be given 15 minutes to plan your first tower. You then have 30 minutes to construct the tower. During the 30 minutes, the instructor will measure the height of each tower. You can request multiple measurements as you proceed with your design and construction. Height will be measured from the top of the table to the top of the tennis ball.

You will have 20 minutes to clean up and plan your second tower. Make a sketch of your tower before you dispose of it, label the parts and record its height. If you have a camera available, take pictures of the structure. Discuss with your teammates what worked and did not work. Discuss how you can improve your design.

**Part 2:** You will have another 30 minutes to make a second tower based on the narrow side of the spaghetti box. You may **not** reuse any materials from the first part of the lab. Sketch and record your second tower before you dispose of it. Discuss what worked and did not work. Discuss how you could improve your design.
1) Deliverables due at the beginning of studio in Week 2
i) Report on your tower-building exercise. (3 pts) Reports can be a maximum of 1 page of text, plus any figures and tables. Include the height of your towers, as well as the heights of the other groups in class. Comment on your relative performance.

ii) Presentation on problem understanding. (PowerPoint, given by 1 person, 5 min) Describe the design problem as your team understands it. Present a list of customer needs and explain which ones are the most important. Present and discuss a House of Quality. Review alternative products currently on the market and describe their strengths and weaknesses. (Any pictures/videos that you obtain from the Internet must have their source clearly indicated.) Summarize your work by stating the most important design objectives. Do not present any preliminary design ideas.

iii) An Excel spreadsheet containing:
A list of all the alternative products that your team located. Give the product name, company, price, and cite your sources of product information.

2) Deliverables due at the beginning of studio in Week 3
i) A presentation on five preliminary design ideas. (PowerPoint, 1 person, 7 min) Display a function tree and point out the most difficult functions to achieve. List your specifications and discuss the most challenging specifications. Describe the functionality of your five preliminary designs. The designs should be distinct from each other. A change in color or size is not sufficient to qualify as a distinct alternative design. Discuss any applicable patents that may limit or influence your design project. Discuss any accidents or lawsuits that are relevant to your design.

ii) A written document containing: (2 pts)
   a) A list of accident scenarios for the product.
   b) A list of relevant accidents. Give whatever descriptive information you can.
   c) A list of relevant patents. Give the patent number, title, and date.

3) Deliverables due at the beginning of studio in Week 4
i) A presentation on your final design (PowerPoint, 1 person, 8 min)

ii) A report containing the following: (10 pts)
   1. Abstract
   2. Introduction defining customer needs and main product function.
   3. Design Overview giving a detailed description of your design including quality sketches (preferably computer-generated) that show its parts and how it operates.
   4. Discussion that presents:
      – Four alternative design solution ideas. (That means 5 total designs).
      – Explain why you chose your design from among the five designs.
      – Explain the advantages and disadvantages of your chosen design.
   5. Conclusions
The report should include a maximum of four pages of text, plus as many figures and tables as necessary. A sample layout of the report is given on the following page; however you are free to add additional sub-headings as you see fit.
Before you prepare your report, you should first read the textbook’s guidelines for using drawings and preparing reports (Chapters 9 and 10).

Title Page

Abstract

Introduction
   Brief description of the design challenge, including the main product function.

Design Overview
   Presentation of your design. (Present your design early in a report so that readers get to the important information quickly. They then have the option of stopping, without reading through the detailed analysis and justifications that follow.)

Discussion
   Presentation of design alternatives and evaluation methods. This is a detailed justification for your design.

Conclusions

References
   You need to document your information sources, including information about alternative products, relevant patents, and relevant lawsuits. Read Chapter 11 of the textbook for proper citation methods and styles. Use the IEEE Editorial Style Manual: http://www.ieee.org/portal/cms_docs_iportals/iportals/publications/authors/transjnl/stylemanual.pdf

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