PROJECT II – DESIGN COMPETITION

Each group will be given clearly defined tasks to achieve using an autonomous device of their own design and will participate in a head-to-head, double-elimination, tournament-style class competition. This semester, you will race to the top of a "mountain". There will be four sides to the mountain. One pair of sides will be long with a shallow slope and the other pair of sides will be short with a steep slope. There may be different obstacles to overcome as your device climbs the mountain. You may choose which side of the mountain to compete on and you may change sides from heat to heat. The fixtures will be made available to you soon so that you can take dimensions, make design decisions, strategize, etc. You are allowed a **maximum total budget of $200** for this project (not including parts acquired from our laboratory).

The Tasks

1. Each heat will have two autonomously competing devices. The winner of a heat is determined by the first device to safely complete the correct sequence of tasks.
2. You must manually **place the device in the starting location within 45 seconds** from when we announce, "place your devices." After 45 seconds, you cannot touch your device, except for *one* action to initialize movement (press button, flip switch, etc.). You cannot have further contact with your device after initializing movement.
3. The **entire device must** not be more than 5 inches in length and 4 inches in width. There is no limit on height. The **entire device must** weigh less than 3 pounds and contain functionality designed to perform all other tasks listed below. The **center of mass** of the **device must** remain within the track boundaries and no more than 4 inches above (orthogonal to) the track surface.
4. The device may be started automatically or manually, as long as the device is not touched or manually remotely controlled after the start of a heat. After movement has been initialized, the device **dimensions may change** (increase or decrease) but **cannot exceed** a 1-inch increase in any dimension (length, width, height). The **device must** remain a single system and cannot separate into multiple subassemblies.
5. The **device must** then traverse the track in the designated direction and reach the top of the track.
6. The **device must** always have at least one contact point with the track during the heat (no jumping, flying, etc.).
7. The winner of a heat will be the device that reaches the top of the track first. The top of the track is defined as the horizontal top surface of the hill. The **entire device must** be on the top surface to achieve this task.
8. If neither device completes the required tasks within 5 minutes, then both devices will compete against each other in a second heat. Teams will have up to 5 minutes to repair any damage to their device. If during the rerun, neither device reaches the top, then both devices will be deemed to have lost the heat.
9. If at any point during a heat your device is clearly failing and could burn out if left running, you are allowed to stop your device and forfeit the round to keep your device in working condition. For double-elimination tournaments, this will allow your team to compete in the next round with a functional device.

Detailed Competition Rules

1. The competition will be double elimination. The schedule of the rounds and heats and how the winners and losers move from round to round will be available prior to the day of the competition.
2. The device trials will be used to determine safety of your device. Items deemed unsafe must be changed prior to the competition and any additions between the trials and competition that could be a safety concern must be approved by a TA. If you have concerns or questions, contact your TA.
3. Gross violations of the safety rules will result in your group's device being eliminated from the competition. Examples of gross violations include damaging (or altering) the fixture, including the use of adhesives or heat on the fixture. When judging whether a safety violation is a gross violation, we will also look at your design intent and what you did to ensure that a safety violation could not occur.
4. Your device can be made from any materials that you would like to use. However, you cannot use any energy storage method or device that might be deemed hazardous. Examples of hazardous energy storage devices include, but are not limited to:
    - Explosives, combustion processes, or highly exothermic reactions (such as model rockets)
    - A compressed fluid that might release too quickly
5. If your team is not willing to stand next to your device without protective clothing or safety glasses, your device will be considered hazardous! However, since some individuals are braver than others, the judges reserve the right to deem a device hazardous.
6. You are encouraged to use the test fixtures in Engr A08.
7. No human contact with the device is allowed at any time during the time from the start of a round until that round has been declared finished and the results have been announced.
8. The device cannot contain any biological components. For example, you are not allowed to employ a trained hamster (or very small dog) as part of your device.
9. Your team must check into the registration table at the designated time. If your team is more than 5 minutes late, and this is deemed to hold up the competition, your team will lose its first round.
10. Your team will be disqualified if your device intentionally or unintentionally damages the fixture in any manner including but not limited to: breaking any part of the fixture, overheating any part of the fixture, or generating noticeable nicks or notches that will impact the integrity of the competition.
11. Judging. Your TA will determine which device accomplished which tasks during each round. The TA is also the primary referee to observe any safety violations. Device weights will be recorded at check-in and may be rechecked later if devices have been modified.
12. Protests. All protests must be registered immediately after the competing round. You must qualify your protests based on the ground rules and the project definition. Keep good engineering records (engineering book) of your development process to use to defend your

positions. If you have no supporting documentation at the day of the competition, your protest will be disallowed. The course instructor will be the final judge on all protests.

13. This competition is a lot of fun and an opportunity to cheer for and encourage everyone. Feel free to invite your friends and family as well.
14. Can we use a spring? There's no problem in using a spring, rubber band, or other means of propulsion as long as it does not generate so much force as to be dangerous. Using a crossbow, for example would be considered dangerous because we don't think any of your team members would feel safe standing in front of it.
15. Can we grab our device after it completes the task? Not until the round has been declared completed.

Judges Decisions Disclaimer

In a competition of this nature it is hard to anticipate all the interpretations of the rules and situations that will arise in the competition. Therefore, the judges will decide anything not covered by these rules and the interpretations of these rules. These rules are subject to optimization and may be altered by the staff to preserve the "spirit" of the contest.

The Rewards

1. The 1st place team will receive a **1.5-point increase** to *each* team member's final **course grade**.
2. The 2nd place team will receive a **1.0-point increase** to *each* team member's final **course grade**.
3. The 3rd place team will receive a **0.5-point increase** to *each* team member's final **course grade**.

Note that all three **winning teams must** be **present** during the lecture on **May 7th** to explain to others in the class how you designed your device and some of its more successful features.

We will ask other faculty members to help judge the devices for other areas of merit, which might include:

- Manufacturing craftsmanship
- The use of mechatronics
- Design simplicity and elegance
- Low cost

Sharing the Experience

After the competition, we would like to keep your device until after next semester's competition. We have a display area where devices can be seen by anyone.

Design Confidentiality

The TAs and instructor agree to hold discussions about device design and competitive strategies confidential. If the discussion leads to items of general interest (e.g., rules, competition, or grading clarifications), the design group agrees to allow the publication of those items of general interest.

Otherwise, any discussion of a competitive nature leading to a competitive advantage for the group will be held confidential.

Required Design Review

The following requirements will be due throughout the semester to aid in the successful and timely completion of your project.

1. A first draft of your project plan, including a Gantt chart. This must show the date on which you are expected to start system testing, which is a key milestone for this project.
2. A first draft of your specification development, engineering analysis, concept generation, and concept selection as described in the sections below.
3. A first draft of your FMEA and FTA failure analyses.
4. A prototype implementation of your design.
5. Testing trials to demonstrate the success of your device prior to competition.

Required Report

All groups are required to submit a final report detailing your design process and engineering analysis. **Your grade for this project will be based entirely on the report** that you submit, except for the following:

- Only 1st, 2nd, and 3rd place groups will receive a grade bonus based how the device performed in competition.
- Extra points and accolades may be awarded for exceptional engineering work that has exceeded instructor expectations.
- We reserve the right to further lower your project report grade for the project if we feel that you did not make a serious effort to build a device capable of meeting the design tasks.
- Students with consistently poor peer evaluations, which indicate a lack of commitment and contribution to the project workload, will receive a lower project grade than their teammates.

The Deliverable

Your group must prepare a formal design report with the following content in the order provided:

1. **Cover Sheet** (3 Points)
    a. Title and date
    b. Course name & Group number
    c. Name and email address of each team member
    d. A photo of the device to fit in the remainder of the space on this page
2. **Table of Contents** (3 Points)
    a. List of sections with page numbers referenced
    b. List of figures with page numbers referenced

c. List of tables with page numbers referenced

3. **Design Problem Statement** (6 Points)
   a. Give a clear and concise definition of the problem and the intended objectives.
   b. Include appropriate background on the project for the reader to be able to put the information provided in context. Assume the reader is totally uninformed about your project.
4. **Specifications Development** (27 points)
   a. Describe how you developed the specifications (constraints and objectives) for your device and its various systems. Your specifications development should be as clear and easy to follow as possible. Include drawings, charts, equations, etc. to assist in the explanation of specifications. Your specifications should attempt to quantify as much as possible using measurements that can later be verified. Prioritize the needs and wants for functional specifications and list all constraints.
   b. A full Quality Function Deployment (QFD) analysis (**template**).
   c. Identify the target customers for your device.
   d. Show the customer requirements developed (**template**), how these requirements were determined, and their relationship to the target customers for your device.
   e. A description of the research you performed to identify other designs of similar products and what you learned from them. This should include a list of any patents studied and links to any articles read online. Use multiple types of data sources (reviews, product data sheets, patents, technical papers, etc.) and provide multiple examples of each type of data source.
   f. List 2—4 competitors to your device and how they compare to your device in meeting customer requirements. You don't need to buy competing devices. You can use any publicly available information to make your comparisons.
   g. List the specifications that your device must meet based on the requirements previously identified and how the specifications link to the requirements.
   h. Identify tradeoffs between specifications.
   i. Establish specification targets.
5. **Concept Generation & Selection** (30 points)
   a. There should be a description of the concepts your group considered, the methods used to generate concepts, and the process used to make the choices that led to the design (or designs) your group decided to build and test as prototypes. The conclusion of this section needs to tie back to the specifications, constraints, and analysis performed in the steps above.
   b. Generate a minimum of three design concepts (Morphology & Design for Assembly (DFA) *optional* **templates**).
   c. Evaluate these concepts relative to the specifications, targets, and competitors' devices.
   d. Include one or more detailed sketches and a description of each of your design concepts.

6. **Bill of Materials (BOM)** (15 Points)
    a. Bill of materials (**template**) listing **all parts** in the device, the manufacturing processes used to make the parts, and the source for each part (how the item was obtained).
    b. Number the parts so that they may be referenced in other portions of the report.
    c. Also include the cost of each item required to fabricate your device. Include the total cost to build the device. One option is to use the Cost Estimator (*optional* **template**) for parts machined yourself.
    d. Finally, tell us how much in total you spent (including spares, parts you didn't end up using, things that broke, etc.).
7. **Device Description** (45 Points)
    a. Reverse engineering process (**template**), including a detailed description of how the device functions (how it works in general and how the important components interact with one another). Include pictures of the system that display moving parts involved in the steps you describe. Sufficient detail should be provided such that the reader could recreate the device without any additional information.
    b. An annotated exploded assembly diagram (solid model *or* picture) of the device. Each item in the exploded assembly should have a reference number relating it to the bill of materials.
    c. A design structure matrix (DSM).
    d. You will be evaluated on the quality and level of detail and engineering understanding demonstrated in this section of the report.
    e. Describe the process (movement steps and sequence) of how your device has been designed to accomplish the required tasks.
    f. Describe any critical elements or features that make your device work and work reliably.
    g. Mention any clever ideas that you think makes your device unique.
    h. You are not *required* to create CAD drawings or solid models, but you can use CAD to help you generate your design prior to fabrication. CAD can also be used to generate the images that explain how to build your device and how it works. If you do create any models, include the important images in the main body of the report.
8. **Engineering Analysis** (30 points)
    a. Demonstrate how you have used engineering knowledge (such as Statics) to help understand and solve the design problems you faced.
    b. Include any other type of analysis or resources used to design and validate your device functionality.
    c. This is an important section of the report and has historically been significant in the report grades and success in the competition.
9. **Testing** (21 points).

a. Describe the tests you performed to verify that your device could meet the specifications you established as part of your QFD. This should be in the form of a test plan that describes each test you performed (Test Report **template**).

b. Show the actual test results from the tests that you conducted according to your test plan. Use tables, graphs, etc. – whatever best conveys the results.

c. Note that for your specifications, it is the best to have target values, not just a yes/no or pass/fail. The same is true for testing. It is best to have actual values (such as your actual device weight, or average and standard deviation of distance traveled), not just whether it passed or failed a particular test.

10. Reliability Analysis (18 points)

a. Failure Modes and Effects Analysis (FMEA) (**template**)

b. Fault Tree Analysis (FTA)

c. Identify and statistically analyze the key areas of variability that will affect the performance of your device and the ability of your device to accomplish all tasks.

d. Analyze your test results from the previous section and anticipated variability to identify how to make your design more robust.

e. List improvements made to your device based on the analysis that you performed.

11. Safety Analysis (6 points)

a. A safety analysis of your design or design choices that shows (a) risk areas (b) hazard risk and (c) what your team did to minimize the most critical hazards. See section 8.6.3 of the textbook for a recommended approach.

12. Service & Support Plan (6 points).

a. This should show what you plan to do in case any part of your device should fail and you need to make emergency repairs during competition day. What spares will you have? Who is responsible for a certain repair?

b. Use the previous two sections to help in this assessment. It is recommended to present this information in a table.

13. Project Plan (15 Points)

a. Complete Project Plan **(template)** indicating a sequenced list of tasks, detailed task descriptions, owners, planned task start and finish dates, important milestone dates, actual task start and finish dates, dependencies, critical path(s), weekly status snapshots, estimated hours (per task or student and total estimated for group), and actual hours (per task or student and total for the group).

b. Gantt Chart covering the entire project timeframe. The Gantt Chart must include tasks, owners, planned start/finish dates, actual start/finish dates, dependencies, and weekly snapshots.

14. Team Assessment (12 Points)

a. A description and analysis of how your team worked together to complete the project and what you learned about teamwork (how did the team overcome conflict/issues to successfully complete the project? How were you able to work harmoniously together?).

b. Include as much reference material as possible (team contract, meeting minutes, team health **templates**).

c. Every team member should contribute to this assessment.

15. References (3 Points)

a. Any information, data, figures, etc. included throughout the report that is not of your own creation must be cited using the IEEE format.

b. Citations must be numbered throughout the text, with the citation information listed (by corresponding number) in the "References" section.

16. Appendices (0 Points)

a. As needed for the following types of information:

b. Detailed computations and computer-generated data.

c. Manufacturers' specifications.

d. Original laboratory data.

17. Design Review (45 points)

a. This is not a section of the report, rather these points will be awarded based on the level of thought and depth shown in your design prototype, your device's performance during the testing trials, and your device's performance during the competition.

18. "Wow" Factor (15 Points)

a. This is not a section of the report, rather these points will be awarded based on obvious and deliberate effort to produce a professional, organized, and accurate project report.

b. Demonstrate initiative by including additional *relevant* material.

c. Demonstrate critical thinking in the analysis.

d. See "The Grading" section of this document for details.

Failure Analysis

If you did not finish in the top three groups of the competition, you are required to write a failure analysis describing why your device did not win and how you would improve your device if the competition were held again. **Your grade in the class will be Incomplete until the failure analysis is submitted.** Failure analyses that do not demonstrate critical thinking and an intention to improve will be deemed unsatisfactory and the overall course grade will remain incomplete until a satisfactory report is submitted.

List of Available Templates

See *Pages* in Canvas:

1. Meeting Minutes ***Required***
2. Team Health ***Required***
3. Team Contract ***Required***
4. Project Plan ***Required***
5. Customer Requirements ***Required***
6. Reverse Engineering ***Required***
7. Bill of Materials (BOM) ***Required***
8. Quality Function Deployment (QFD) ***Required***
9. Design for Assembly (DFA) ***Optional***
10. Morphology ***Optional***
11. Test Report ***Required***
12. Manufacturing Cost Estimator ***Optional***
13. Failure Modes and Effects Analysis (FMEA) ***Required***

The Grading

80% of the points are awarded based on a review of the completeness, accuracy, and quality of the report sections identified under "The Deliverable". The relative importance of each section can be determined by the point values noted above. The report should be typed, formatted, and written in a professional manner – something that you would be proud to share with a prospective employer. See Canvas for examples of quality reports but note that these reports are from previous semesters and may be organized differently or lack some of the current requirements. All diagrams, figures and tables should be accurately and clearly labeled with meaningful names and/or titles. When there are numerous pages of computer-generated data, it is preferable to put this information in an appendix with an explanation in the report narrative.

In addition, 15% will be based on your team's pre-competition device evaluation and your competition performance. The pre-competition evaluation includes a review of the design prototype and testing trials of the prototype.

The remaining 5% of the points are based on the "wow" factor of your report. Examples from previous reports include:

- Reports that looked significantly more professional or clear than the others.
- Superior visual presentation throughout the report.
- Exceptionally good technical research and analysis.
- Particularly clever design feature(s), well-supported by analysis.
- Excellent detail about how your team functioned and how team-related issues were addressed.

- Additional information that is relevant, but not requested.
- Tasteful, clever, and relevant humor.

To summarize: completeness, accuracy, professionalism, and initiative are key ingredients of a good report. Each group is encouraged to first strive for **completeness** by confirming all requirements of the report have been included. Then, check that everything is **accurate** (e.g., review data, calculations, dimensions, etc.). Next, present the work in the most organized and **professional** manner possible. Finally, you are encouraged to include *relevant* additional materials that demonstrate your group went beyond the base requirements to complete this project.