Table of Contents

INTRODUCTION .................................................................................................................................................. 4

TABLE 1. OUTLINE OF MILESTONES FOR THE ROLLER COASTER PROJECT ................................................................. 4

PROJECT OBJECTIVES ........................................................................................................................................ 5

THE ROLLER COASTER REQUIREMENTS ............................................................................................................... 6

ROLLER COASTER CONFIGURATION REQUIREMENTS ................................................................................................. 6

SPEED SENSOR REQUIREMENTS .............................................................................................................................. 7

FEATURE DEFINITIONS ............................................................................................................................................ 7

FEATURE SCORING .................................................................................................................................................. 8

OPERATIONAL REQUIREMENTS .............................................................................................................................. 8

ROLLER COASTER CONSTRUCTION MATERIALS ......................................................................................................... 9

TABLE 2. ROLLER COASTER CONSTRUCTION MATERIALS ............................................................................................. 9

LAB MANAGEMENT .................................................................................................................................................. 10

INITIAL PAPER DESIGN (6% OF COURSE GRADE) .................................................................................................... 11

GOAL ........................................................................................................................................................................ 11

LOGISTICS ............................................................................................................................................................... 11

TIMELINE ................................................................................................................................................................. 11

REQUIREMENTS FOR ROLLER COASTER INITIAL PAPER DESIGN .............................................................................. 11

Drawing (40%) ......................................................................................................................................................... 11

Calculations (40%) ................................................................................................................................................... 11

Initial design Feature list (5%) .................................................................................................................................. 13

Other Design Questions (10%) ............................................................................................................................... 13

Energy analysis spreadsheets (5%) .......................................................................................................................... 13

INITIAL PAPER DESIGN GRADING GUIDELINES ..................................................................................................... 14

PROJECT MANAGEMENT GUIDELINES .................................................................................................................. 15

PROJECT PLANNING AND SCHEDULING ................................................................................................................ 15

Introduction .............................................................................................................................................................. 15

Tasks for the Roller Coaster Project .......................................................................................................................... 15

PROJECT SCHEDULE GRADING GUIDELINES ...................................................................................................... 17

PROJECT NOTEBOOK ............................................................................................................................................ 18

DESCRIPTION & REQUIREMENTS ............................................................................................................................ 18

PROJECT NOTEBOOK GRADING GUIDELINES .................................................................................................... 19

TESTING OF THE ROLLER COASTER ....................................................................................................................... 20

PRELIMINARY TEST OF THE ROLLER COASTER ...................................................................................................... 20

FINAL TEST OF THE ROLLER COASTER ................................................................................................................ 20

SCORING FOR THE FINAL SYSTEM TEST ........................................................................................................... 20

Roller Coaster Final Test Grading Sheet .................................................................................................................. 21

FINAL REPORT ......................................................................................................................................................... 22

DRAFT FINAL REPORT .......................................................................................................................................... 22

FINAL WRITTEN REPORT: SUGGESTED FINAL REPORT DETAILS ............................................................................. 22

FINAL REPORT GRADING GUIDELINES ................................................................................................................ 27

ORAL PRESENTATION ........................................................................................................................................... 28
INTRODUCTION

In the competitive amusement park industry, engineers are responsible for continually innovating and developing exciting new roller coaster rides while still being constrained by the laws of physics and by safety requirements. As part of the lab in Engineering 1182, your team will design, build, document and test a model roller coaster. The design/build project consists of several different kinds of labs:

1. An introductory lab, where you will measure structural components and build a sample section of roller coaster in order to get an idea of how the components fit together.
2. A basic roller coaster physics lab, where you will gather information about energy losses that will aid you in the design of your coaster. You will use two production versions of the speed sensor to instrument a horizontal curve and investigate energy losses as a function of g-force and track support. You'll need to use up to eight of these sensors to instrument your actual coaster.
3. This is followed by an electronics lab where you will prototype a speed sensor to measure the speed of the roller coaster ball at a given point on your roller coaster track.
4. The fourth lab is for you to understand calibration of the LED speed sensors using different techniques.
5. Then, you'll finally, there are three construction labs, where you will build and test the coaster. The last two lab periods are for final coaster testing and an oral presentation about the coaster. A competition is held among all the coasters in the lab during the final test session.

| Milestone 1 | Review Project Design Document |
| Milestone 2 | Work on paper design, Begin Project notebook |
| Milestone 3 | Due: Initial paper Design, Update Project Notebook |
| Milestone 4 | Due: Project Schedule, Update Project Notebook, Begin construction |
| Milestone 5 | Construction, Update Project Notebook |
| Milestone 6 | Preliminary testing, Draft Final Report, Update Project Notebook, |
| Milestone 7 | Due: Update Project Notebook, Final System Testing |
| Milestone 8 | Oral Presentation, Due: Final Written Report/Final Design, Due: Completed Project Notebook |
PROJECT OBJECTIVES

Project Management and Teamwork – To successfully bring any complex project to completion requires proper planning and the coordinated effort of a group of people. To help your team achieve this goal, you will be introduced to the basics of project management and teamwork. This includes, but is not limited to: time management and task scheduling, team communications and meetings, fair division of labor and team member responsibilities. You will be expected to produce related documents such as a work breakdown structure, a project schedule, and team meeting records, all of which must be regularly updated and kept in the team project notebook. Additional information is included in the Project Management and Project Notebook sections of this document.

Design Process – Rarely, if ever, does a new design work perfectly the first time. Your roller coaster will likely be no exception to this. While it is a lot of fun to dive right in and start prototyping any sort of project, your team will reach a useful design much sooner if you follow a more formalized approach to the design process. In short, it consists of: identifying the project requirements and constraints, gathering background information, brainstorming, identification and management of materials, preliminary analysis & initial design, and the build/test/modify/document cycle. As part of this process, you will produce the initial paper design of your roller coaster, document any revisions to it as they occur, and produce a final paper design that accurately reflects your final coaster design. You should also keep the initial and final paper designs, with all revisions, in your project notebook. For more details, read the Initial Paper Design, Project Management and Project Notebook sections of this document.

Project Documentation – Your project documentation consists of three parts: the team project notebook, the oral presentation and the final written report. The team project notebook is the complete documentation of the roller coaster project, and which will be reviewed on a weekly basis. It should contain your lab memos, paper design, team meeting minutes, project management documents, and anything else of importance relating to the roller coaster. The complete requirements are in the Project Notebook section of this document. The final oral presentation is an overview of your roller coaster design experience. The final written report is a complete summary all aspects of your design. The oral presentation and final written report are both due in the last week of the semester – see your course website for the exact date. The requirements for each of these are described in detail in the Oral Presentation and Final Written Report documents. Other references are: Technical Communication Guide on EED course website.
THE ROLLER COASTER REQUIREMENTS

The roller coaster is a simple open-loop coaster, meaning that it does not have any physical connection from the end back to the beginning. Photos are shown on the cover page of this document. The track rails are made of two 25’ lengths of 1/4” inch OD polyethylene tubing, connected to the support structure by snap-fits. The snap-fits also serve as spacers to maintain the proper spacing of the coaster rails. The snap-fits are attached to the track support structure by nylon strap clamps and their associated hardware. The support structure is made of 1/2” plastic (CPVC) tubing and various kinds of piping connectors. You will be provided with a wood and CPVC tower to use to support the start of your track.

Roller Coaster Configuration Requirements

These are the requirements relating to the physical layout of the roller coaster and the minimum set of required features. These will be evaluated during reviews of the paper design, and again during preliminary test. They will be graded during final test.

Your team will build an open-loop roller coaster that includes the following ‘minimum required features’. The features will be defined in the following section.

- Vertical loop
- Horizontal loop
- Bump
- Straight horizontal

To get the maximum score for your roller coaster, you will need to either modify these features to more complex versions, such as a cobra, or add features. A list of standard features is given on the next page. Scores for these features are given in the final testing section. If you want to introduce a feature not on the list, ask your instructional staff ahead of time about how it will be scored. For example, you could construct your coaster in less than half the allowed horizontal space.

In addition to the minimum set of features, your coaster will need to meet the following requirements:

- Your roller coaster design must use the full 25’ of track provided – in other words, you must start the ball within 6” of the start of the track, and the ball must finish by dropping off the other end of the track into the catch bin. Note that if you build your coaster with more turns one direction than the other, then at the end of the track one piece of tubing will be longer than the other. The requirement is that the ball stays on the track until the end of the shorter piece of tubing.
- Roller coaster dimensions: The roller coaster track must fit on the lab table top, inside a space that is 5’ long, 4’ wide, and using the provided starting tower. (Use of the tower is optional if your design suggests something else, but the same conditions apply.) Portions of the starting tower may be outside these dimensions, however the track attached to it may not be. The starting tower may be extended in height by no more than one standard 6” pipe piece and one fitting attached to the
top end of that. The track may extend no more than 2” beyond that to allow for a snap fit and associated mounting hardware. The starting tower cannot otherwise be modified.

- A catch bin to catch the ball constructed from the supplied cardboard sheet.
  - The bottom area of the bin can be no more than 9 square inches.
  - The level of the top of the bin must be at least 3” below the level of the end of the track
  - The bin must be on but not attached to the tabletop, nor may it have tape or other adhesive inside to capture the ball.

**Speed Sensor Requirements**

**Speed Sensor locations:** You will also be provided with eight speed sensors with which to instrument your coaster. One must be about 1 cm after the start of your coaster, one at the end within 1 cm of where the ball falls off, one at the top of a vertical loop, and one at the top of a bump.

In addition to the four speed sensors in required locations, you will need to place four additional sensors to determine in which features of your coaster there are the most significant discrepancies from the spreadsheet calculations.

**Feature Definitions**

- **Vertical loop** – a loop with horizontal axis around which the track traverses 360° (or more)
- **Double vertical loop** – a loop with horizontal axis around which the track traverses 720° (or more)
- **Horizontal loop** – a loop with vertical axis around which the track traverses 360° (or more)
- **Double horizontal loop** – a loop with vertical axis around which the track traverses 720° (or more)
- **Upward horizontal loop** – a loop with vertical axis around which the track traverses 360° (or more) and which trends upward during the loop
- **Double upward horizontal loop** – a loop with vertical axis around which the track traverses 720° (or more) and which trends upward during the loop
- **Figure 8** - Connected horizontal loops with clockwise and counter-clockwise turns. Viewed from the top, the track should look like the number 8.
- **Bump** – the bump is required to have a minimum height of 1” with a maximum length of 4 times the height. For example – a bump of 2” height must have a length of 8” or less.
- **Rise** – a section of track with an upward slope of at least 25°
- **Straight horizontal run** – a section of straight horizontal track, of at least 12” in length.
Feature Scoring

Points for each of the features included in the roller coaster design will be added to create the feature score. A coaster with the ‘minimum required features’ will have a score of 34, resulting in a maximum score of 84 for the final test. There will be a penalty of 5 points for any required feature that is not present in the design. Thus a coaster with no bump, but a double vertical loop, a horizontal loop and a straight section would receive 29 points (34 points for the included features minus the 5 point penalty). Any complex features that include any of the ‘minimum required features’ will satisfy the ‘minimum required features’ criteria. (For example - a Figure 8 satisfies the requirement of a horizontal loop) Only two of a given type of feature may be counted, so ten bumps would only be worth 12 points. A coaster may count both a double vertical loop and a separate single vertical loop for 30 points or a double downward horizontal loop and a separate upward loop for 31 points. Inclusion of exceptionally difficult features, e.g. a double upward loop, a corkscrew, or a cobra, will allow the total feature points to reach 55 (an extra credit of 5 points). The feature score cannot exceed 55 points Features not described will be allocated points based on the discretion of the instructor, but the instructor must be notified no later than preliminary testing about the features to be considered.

Vertical loops:
   Single   12 points
   Double   18 points

Horizontal loops:
   Single Downward  10 points
   Double Downward  15 points
   Single Upward    16 points
   Double Upward    24 points

Figure 8:            16 points
Design includes both clockwise and counter-clockwise turns (independent of a figure 8)  8 points
Straight Section:    6 points
Bump:                6 points
Rise:                4 points

Operational Requirements

These are the requirements that must be met while running the ball on the coaster track. These requirements will be evaluated during preliminary test and graded during final test.

- To start the run, you will release the ball within 6” of the start of the track.
- The ball must stay on the track at all times during the 25’ running length (until the end of the shorter piece of tubing).
- The attached sensors must detect the passage of the ball during a normal coaster run and the resulting speeds must be displayed.
- At the end of the run, the ball must drop into the catch bin, without bouncing out, and without tipping it over.
- You must be able to assemble the roller coaster in 30 minutes or less. Assembled means all support structures built and the entire track attached. The ball does not need to successfully roll through the coaster at this point. Assembly will be timed during the final system test.

ROLLER COASTER CONSTRUCTION MATERIALS

Each team will be provided with standard roller coaster kit, parts for the sensor circuits, and a storage bin. The roller coaster kit includes the following materials plus eight speed sensors and associated hardware:

Table 2. Roller Coaster Construction Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snap-Fits</td>
<td>90</td>
</tr>
<tr>
<td>1/4” OD poly tubing – 25’ lengths</td>
<td>2</td>
</tr>
<tr>
<td>10-24x1/2” steel shoulder thumb screw</td>
<td>35</td>
</tr>
<tr>
<td>10-24 square nut</td>
<td>35</td>
</tr>
<tr>
<td>Nylon loop strap, .63” ID</td>
<td>35</td>
</tr>
<tr>
<td>1/2” CPVC 90° drop ear elbow</td>
<td>16</td>
</tr>
<tr>
<td>1/2” CPVC tee</td>
<td>50</td>
</tr>
<tr>
<td>1/2” CPVC coupler</td>
<td>24</td>
</tr>
<tr>
<td>1/2” CPVC 90° elbow</td>
<td>16</td>
</tr>
<tr>
<td>18” CPVC pipe</td>
<td>12</td>
</tr>
<tr>
<td>12” CPVC pipe</td>
<td>16</td>
</tr>
<tr>
<td>6” CPVC pipe</td>
<td>30</td>
</tr>
<tr>
<td>4” CPVC pipe</td>
<td>30</td>
</tr>
<tr>
<td>3” CPVC pipe</td>
<td>20</td>
</tr>
<tr>
<td>2” CPVC pipe</td>
<td>20</td>
</tr>
<tr>
<td>Cardboard 8-1/2”x11”</td>
<td>1 sheet</td>
</tr>
</tbody>
</table>

No additional track and structure materials may be used. Eight speed sensors will be supplied during the semester. A semester checklist must be completed when each team receives these materials and will be used for check-in of materials after final testing.

Duct tape cannot be used to attach the track supports to the table. Marking on or cutting of the track or track support materials is prohibited. If labeling is required for speed of construction, make labels with masking tape, and ensure that all labels are removed before checking in the equipment at the end of the semester.
LAB MANAGEMENT

- Policy on Missing Lab Building Sessions
  - For each unexcused absence from a building session, 20 points (20%) will be deducted from the final system test grade.

- Lab Safety
  - **Do not stand on the chairs, or sit or stand on the lab tables**
    - Always know the location of the first-aid kit
    - Report all injuries occurring in lab to the instructional staff

- Storage bins
  - Since the roller coaster must be disassembled between lab sessions, a storage box of approximately 12”x12”x18” will be provided to each team
  - Storage bin lids must close – for security reasons; you must shut the bin at the end of each lab period. Be sure that nothing that is supposed to stay on the lab table goes in your storage bin.
  - Be sure to properly protect your circuit. If you do not, you will likely have to spend significant amounts of time debugging it.

- Checklists
  - At each table, tools and equipment will be available according to the weekly lab checklist. **These must remain at the table.**
  - At the beginning of the lab period, verify that all the material required by the checklist is present at your lab table. If anything is missing, note it on your weekly checklist, and inform the instructional staff.
  - At the end of the lab period, one of the instructional staff will complete the weekly checklists with you. Be sure to include them in your lab memos.

- There are no supplemental lab hours. All construction work must be completed within the scheduled lab times.
INITIAL PAPER DESIGN (6% OF COURSE GRADE)

Goal

To develop and document a roller coaster design based on the requirements listed in this document supported by solid physics principles and detailed speed calculations.

Logistics

Student teams will be required to provide an initial paper design for their roller coaster and have it reviewed by the instructional staff before actual physical construction begins.

Timeline

Your Initial Paper Design is due in the lab two weeks before the first build session. The Initial Paper Design must be reviewed with the instructional staff prior to receiving Roller Coaster parts for construction. Your team will be expected to incorporate the necessary changes resulting from the design review prior to construction. Your team can further modify your paper design as needed based on experimentation and practical knowledge obtained from the first build session onwards. Your modifications will develop into the Final Paper Design by the end of the semester which will be required prior to final test. You will also include it in your team’s final written report. Be sure to incorporate all changes in a timely manner for review in the team project notebook.

Requirements for Roller Coaster Initial Paper Design

Drawing (40%)

The drawing must contain neat, three-dimensional representation (isometric and 3 orthographic views) of the roller coaster. It must include:

- the shape of the track
- an approximate representation of the CPVC parts required to support it along with an initial parts count. Show the parts count list in a table (Table 1). Refer to the table of roller coaster construction materials on page 9.
- location of the speed sensors (four in required locations, up to four positioned to determine energy losses in key features).
- dimensions for track and structure

Calculations (40%)

Velocity must be calculated for the entry and exit of all segments/features of the design including the start and end of the track. These calculations must include friction and can be done using the Excel spreadsheet demonstrated in class. Identify the entry and exit of all of the features of your roller coaster and label them on your sketch. Create an Excel spreadsheet with all elements of your track included and the velocity in and out of each. A partial example
is shown below:

**Table 2. Roller Coaster Theoretical Calculations (Example)**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Velocity_in (m/sec)</th>
<th>Velocity_out (m/sec)</th>
<th>Track Length (m)</th>
<th>Bank Angle (deg)</th>
<th>$\sqrt{gr}$ (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start to first feature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical loop start to top</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical loop top to end</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical Loop to 25° rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last feature to end</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal Dist. to bin (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Track Length (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Identify units of calculations*  
*Verify total track length is 25 feet (sum the track length column and check if it is 25 feet = 7.62 m)*

**In addition to the above mentioned calculations perform the following calculations:**

1. Velocity at top of the vertical loop  
2. Compare velocity to $(gr)^{1/2}$ at top of vertical loop  
3. Banking Calculations for all horizontal curves including horizontal loop  
4. Bump velocity at top of all bumps compared to $(gr)^{1/2}$  
(Provide the calculations in Table 1)

**NOTE:** An Energy Analysis Spreadsheet is available and used to assist in calculating ball speeds at points along the roller coaster track. This spreadsheet is located on the course website the lecture on Roller Coaster Design Calculations. The spreadsheet requires certain coefficient values if friction is to be accounted for. The coefficients come from Energy Losses Lab data reduction. Refer to your Lab procedure and resultant data to develop the proper coefficients for use in the spreadsheet.
Initial design Feature list (5%)

Create a table (Table 3) listing the roller coaster features of the initial design and the associated feature score.

Table 3. Roller Coaster Initial Design Feature List

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Feature Score

Other Design Questions (10%)

1. Will your coaster fit into the required length, width and height? List these (3) dimensions in meter.
2. Have you used only the parts provided in your kit, and no more? Refer to the Parts List which you provided for the drawing.
3. What is the longest section of unsupported track? Do you think this is an acceptable length? Why or why not?
4. Are any bank angles exceeding 45 degrees? If so, please list them. Do you think it is acceptable to have these angles? Why or why not?
5. Have all 25 feet of track been used? Provide exact length.
6. Are all velocities less than \((2gh)^{1/2}\), where \(h\) is the initial height? Provide sample calculation.
7. Are all velocities going out less than the velocities going in, except from top of vertical loop?
8. What is the critical angle? Has the critical angle been exceeded at anyplace? If so, where?
9. How will you assemble/disassemble parts for storage? Provide a well-thought out process.

Energy analysis spreadsheets (5%)

Turn in 5 completed energy analysis spreadsheets (one each) for the following features of the roller coaster (1% for each spreadsheet): DROP, STRAIGHTAWAY, VERTICAL LOOP, HORIZONTAL LOOP, and BUMP.
# Initial Paper Design GRADING GUIDELINES

**DOCUMENT GRADED:**  INITIAL PAPER DESIGN

**TEAM DESIGNATION:**  

<table>
<thead>
<tr>
<th>ITEM</th>
<th>POSSIBLE POINTS</th>
<th>POINTS EARNED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONTENT:</strong></td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
| • Drawing  
  Include: one isometric view and three orthographic views.  
  1. The shape of the track  
  2. A parts list (Table 1)  
  3. The location of speed sensors  
  4. Dimensions for structure and track | 40 | |
| • Calculations (Table 2)  
  Include: 1. Entry/Exit velocities for all features  
  2. Velocity at top of vertical loops and comparison to \((gr)^{1/2}\)  
  3. Banking calculations for horizontal curves and loops  
  4. Velocity at the top of bumps and comparison to \((gr)^{1/2}\) | 40 | |
| • Feature List (Table 3) | 5 | |
| • Design Questions | 10 | |
| • Energy Analysis Spreadsheets  
  Include five features: Drop, Straightaway, Vertical Loop, Horizontal Loop and Bump | 5 | |

**TOTAL POINTS**  100

**Grading Guidelines** – 2 points will be deducted if these guidelines are not attached to the Initial Paper Design.
PROJECT MANAGEMENT GUIDELINES

Project Planning and Scheduling

Introduction

An important part of any project is proper planning early in the process. This involves identifying and analyzing the requirements, translating them into tasks, and then mapping the tasks to the available resources and timeframe. For the roller coaster project each team should examine the course website and read the project description document to understand all of the deliverables required for this project. Using this information and taking advantage of the skills of the members of your team, you can then start more detailed planning and scheduling. This project schedule becomes an important tool for your team to use throughout the project execution to determine your progress toward your deadline.

The project schedule should be reviewed and updated at least weekly to identify tasks completed and status of your work. If initial tasks fall behind or overlooked tasks are identified, a re-plan effort needs to be done to establish a revised plan to meet the project deadline. This project schedule will be evaluated weekly by the instructional staff.

At the beginning of the first build session each team will be required to submit a project schedule for their roller coaster. This submission is required before any construction can begin. At the last lab, the final version of the project schedule should be included in project notebook for grading. Below is a list of tasks that must be included in your schedule. You can add other tasks as you feel appropriate to allow you to manage your project. You should assign team members to them and identify a planned start and finish time for each task along with any dependencies between tasks. A sample of such a project schedule is shown following Task list.

Tasks for the Roller Coaster Project

Read project description document
Team working agreement
Team design brainstorming session(s)
Develop initial project plan
Notebook updates
Introduction to Roller Coaster memo
Energy Losses Lab memo
Circuit Prototyping Lab memo
Sensor Calibration Lab memo
Team design meetings
Initial paper design
Revisions from design review meeting incorporated into paper design
Plan for division of work during lab time
Initial construction begins
All features built
Ball rolls through entire roller coaster
Mounting of speed sensors
Building of capture bin
Initial testing of completed design
Verifying 30 minute build time
Preliminary Test
Final Test
Prepare final paper design
Performance analysis using speed measurements
Final Written report – outline, draft, final
Oral Presentation – outline, draft, final, actual presentation

A Sample project schedule is shown below.

<table>
<thead>
<tr>
<th>Task</th>
<th>Assigned Person</th>
<th>Planned Start</th>
<th>Actual Start</th>
<th>Planned Complete</th>
<th>Actual Complete</th>
<th>Completion Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Browse course website and read project description</td>
<td>All</td>
<td>9/12/2014</td>
<td>9/12/2014</td>
<td>9/14/2014</td>
<td>9/16/2014</td>
<td>100%</td>
</tr>
<tr>
<td>Start project notebook</td>
<td>R. L. K</td>
<td>9/27/2014</td>
<td></td>
<td></td>
<td>10/1/2014</td>
<td></td>
</tr>
<tr>
<td>Initial paper design</td>
<td>All</td>
<td>10/11/2014</td>
<td></td>
<td></td>
<td>10/16/2014</td>
<td></td>
</tr>
<tr>
<td>Etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Project Schedule GRADING GUIDELINES

<table>
<thead>
<tr>
<th>Project Schedule</th>
<th>Possible Points</th>
<th>Points Earned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content:</strong></td>
<td>8pts</td>
<td></td>
</tr>
<tr>
<td>• Tasks (20 minimum)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>• Person(s) assigned</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Estimated start and finish dates</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Actual start and finish dates</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Estimated and actual hours spent</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Deadlines/ due dates</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Percent complete</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Format &amp; Organization</strong></td>
<td>2pts</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>10pts</td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL COMMENTS:**

**Grading Guidelines** – 2 points will be deducted if these guidelines are not attached to the Project Schedule.
PROJECT NOTEBOOK

Description & Requirements
Each team will keep a notebook documenting their progress in the building of their roller coaster project. A three-ring binder is recommended. The purpose of the notebook is to document your work and have a record of ideas and decisions made throughout the semester, in order to create your final written report and oral presentation. Materials should include, but not be limited to, the project description, project schedule, the team working agreement, lab memos/reports, design documentation, handout materials, meeting notes, sketches, and all assignments directly related to the final written report and presentation (see below for list of required elements). Your instructor will check this notebook each week in lab as it counts as part of your grade. The notebook will be turned in the last day of class, along with your final written report.

1. **Table of Contents:** The table of contents should reflect some organizational structure. In the past, notebooks have been organized by type of document (e.g. sketches, meeting notes, lab reports, etc…) and also chronologically.

2. **Project Description:** Include this entire packet of materials about the project.

3. **Team Working Agreement**

4. **Project Schedule:** Your project schedule should be a working document. Each week your schedule should be updated to reflect changes, additions, and modifications.

5. **Lab Memos and Reports:** Simply include lab memos after they have been graded, plus the final written report.

6. **Design Documentation:** Preliminary and final paper design of roller coaster parameters along with all physics and engineering calculations (including MATLAB and/or Excel analysis).

7. **Meeting Notes/Brainstorming Record:** Your meeting notes should accurately reflect the topics discussed and decisions reached (or not reached) in your team meetings. Sketches (if any) should accompany these notes.

8. **Sketches:** The only sketches required here are those not already contained in team meeting notes or lab reports. You should include any free hand or draft CAD drawings outside of the meeting notes or reports, including scrap drawings or ideas not used. Do not include the drawing assignments from class.

9. **Class Handouts:** There is a possibility that you will be given updated project descriptions throughout the semester.

10. All materials relevant to the final written report: drafts of the written report, report outline, etc… (check syllabus)

11. All materials relevant to the oral presentation
Project Notebook GRADING GUIDELINES

The purpose of the project notebook is to document all work undertaken by the team during the course of the semester. When submitted, the project notebook should contain all the information required for the implementation of the project, in a step-by-step or sequential fashion. The project notebook is worth 50 points and the distribution of points and grading guidelines are listed below.

1. **Notebook Organization (10 pts)** – The team can start initial preparation of the project notebook after the first RC Lab. Use a three ring folder or binder. One approach is to print all the project related documents from the ENGR 1182 course website and place it in the Project Notebook, tabbed for easy reference. During the fourth to the ninth labs, the instructor will check the Project Notebook at least five times to make sure that it is up-to-date. **These weekly checks are worth a total of 10 points as part of the process check, which is independent from the notebook grading.**

2. **Grading (40 pts)**
   - **Index and proper page numbering (6pts)**
   - **Updated and neatly written/typed project schedule (10pts)**
   - **All lab related assignments, memos, and final written report (12pts)**
     - All sketches in the final written report should be neatly labeled and titled. Sketch of final design could be hand-drawn or in SolidWorks; pictorial views as well as fully dimensioned orthographic views should be furnished. Any change suggested by the Instructor/GTA to the final design should be implemented by the team. If not the team will lose half the credit of this section (10) and they might lose points during the final project testing as well.
     - **Brainstorming ideas and out-of-class meeting notes (12pts)**
       - Brainstorming ideas – 5 pts
       - Out-of-class meeting notes – 7 pts

3. **Timely submission** – Each team needs to submit the Project Notebook within the first five minutes of the Oral Presentation session. **Any late submissions are subject to a 20% deduction.**
TESTING OF THE ROLLER COASTER

Preliminary Test of the Roller Coaster

A preliminary test of each team's design will take place for debugging purposes. A member of the instructional staff will evaluate the track and structure according to the roller coaster requirements. **The team will not be graded on the basis of the preliminary test.** At this operational check, the roller coaster (including structure and circuits) must be assembled in less than 30 minutes. Special attention should be spent on the requirements of the design such as dimensions of features, angles of rise or fall, etc. so that these adjustments won’t have to be made between runs during final test.

Final Test of the Roller Coaster

A final test of each team’s design will take place. You will be required to provide a sketch of the final design at final testing to verify the structure. A member of the instructional staff will evaluate the track and structure according to the roller coaster requirements and the design evaluation criteria. **The team will be graded on the basis of the final test.** At this operational check, the roller coaster system must be assembled in less than 30 minutes. (Assembled means all support structures built and the entire track attached. The ball does not need to successfully roll through the coaster at this point.)

In order to optimize time usage and promote fairness the following process can be used. Team testing order will be determined randomly by the instructional staff. If a team is not ready when their turn occurs they will not receive any points for that run. The following schedule will be used:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Announcements</td>
<td>5</td>
</tr>
<tr>
<td>Construction</td>
<td>30</td>
</tr>
<tr>
<td>Inspection/Grading</td>
<td>25 (Grading all configuration requirements)</td>
</tr>
<tr>
<td>Trial 1</td>
<td>10 (Measuring operational requirements with ball rolling on track) (after run confirm physical requirements are still met)</td>
</tr>
<tr>
<td>Trial 2</td>
<td>10 (as needed)</td>
</tr>
<tr>
<td>Trial 3</td>
<td>10 (as needed)</td>
</tr>
<tr>
<td>Disassembly and Semester Check-in</td>
<td>20</td>
</tr>
</tbody>
</table>

**Scoring for the Final System Test**

Each team will be offered an opportunity for up to three trials. Each trial will be scored separately out of 100 points and the best score will be the team’s recorded score. Each trial will consist of three consecutive runs of the ball along the track. Points will be awarded per the following Final Test Grading Sheet.
## Roller Coaster Final Test Grading Sheet

<table>
<thead>
<tr>
<th>Team Name:</th>
<th>Points</th>
<th>Score</th>
</tr>
</thead>
</table>

### Roller Coaster Configuration Requirements:

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feature Score</strong> (Sum of all features in the coaster for 50 points, or with allowed extra credit features, a maximum of 55 points)</td>
<td>50</td>
</tr>
<tr>
<td>Catch bin dimensions met</td>
<td>2</td>
</tr>
<tr>
<td>Construction time less than 30 minutes</td>
<td>4</td>
</tr>
<tr>
<td><strong>Roller coaster outside dimensions</strong> (≤ 4’ × 5’, 2 pts per dimension)</td>
<td>4</td>
</tr>
</tbody>
</table>

**Total Roller Coaster Configuration Score** (maximum of 65 points) | 60 | X | X |

### Roller Coaster Operational Requirements:

<table>
<thead>
<tr>
<th>Trial</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ball stays on track until it reaches the end of the track</strong></td>
<td>24</td>
</tr>
<tr>
<td>The sum of three runs worth 8 points each. For each run, teams will be allotted points proportionally to the percentage of the coaster that the ball stayed on the track. A two point deduction if the ball is not started within 6 inches of the beginning of the track.</td>
<td></td>
</tr>
<tr>
<td><strong>Ball successfully triggers all eight speed sensors</strong></td>
<td>10</td>
</tr>
<tr>
<td><strong>Ball drops into and stays inside the catch bin</strong></td>
<td>6</td>
</tr>
</tbody>
</table>

**Total Roller Coaster Operation Score** | 40 |

**Total Score** (maximum of 105 points) | 100 |

### Feature Point Values

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical Loops</strong></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>12</td>
</tr>
<tr>
<td>Double</td>
<td>18</td>
</tr>
<tr>
<td><strong>Horizontal Loops</strong></td>
<td></td>
</tr>
<tr>
<td>Single Down</td>
<td>10</td>
</tr>
<tr>
<td>Double Down</td>
<td>15</td>
</tr>
<tr>
<td>Single Up</td>
<td>16</td>
</tr>
<tr>
<td>Double Up</td>
<td>24</td>
</tr>
<tr>
<td><strong>Additional Features</strong></td>
<td></td>
</tr>
<tr>
<td>Figure Eight</td>
<td>16</td>
</tr>
<tr>
<td>Change of Direction</td>
<td>8</td>
</tr>
<tr>
<td>Straightaway</td>
<td>6</td>
</tr>
<tr>
<td>Bump</td>
<td>6</td>
</tr>
<tr>
<td>Rise</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Features</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Feature Score</strong> (Max 55 pts)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

**Team Feature Score**
FINAL REPORT

Draft Final Report

The draft of the final report will be submitted prior to submitting the Final Report. The structural layout of the draft should be similar to that of the Final Report as discussed in the next section. Depending on the progress of your project, if you’ve not finished the testing of your roller coaster then the data to be reported in ‘Performance Analysis’ and ‘Summary’ section can be marked as ‘under progress’. The draft being submitted should be as close to the final report as possible with remarks regarding the potential information that will be added eventually in the Final Report.

Final Written Report: Suggested Final Report Details

One of the final products you are required to complete is a written report about your design build experience and your final product. To get started, the following outline has been provided to be used as a guide to organizing your report. Use the following as a guide and add in detail where appropriate. The more detailed your outline, the less time consuming your final report will be. Please note, where marked, you should use information from your lab memos. The document following this provides detailed information on writing your final report.

1) Cover Page
   Include
   • Project title
   • Team name and number
   • Names of team members
   • Course name and number
   • DATE!!!
   Hints
   • Be sure that each time a draft or revision of the report is turned in, the date is changed on the cover page.
   • Use a design or team logo on the cover page.

2) Table of Contents
   Include
   • Number of each part or section
   • Part or section titles
   • Page on which each section begins
   Hints
   • The page number for the Table of Contents is "i".
   • If a section is several pages long, in the Table of Contents, give only the number of the first page of the section.
   • Look in some published reports or books for examples.

3) List of Figures, List of Tables
   Include
• Figure number
• Figure title (as it appears in the caption on the figure)
• Page on which the figure is found

Hints
• Assuming that the Table of Contents is only one page long, the List of Figures is on page "ii".
• Look in published reports or books for examples.

Tips on Figures
Few students have experience putting figures in reports. But in technical reports, figures are often very important. The reader must be able to locate the figure and quickly understand how it is related to the text. Here are some tips on figures.

• A figure should have a number and a descriptive title. Some examples follow.
  o Figure 1. Orthographic views of the three-wheeled stroller concept.
  o Figure 7. Graph showing densities of various stroller construction materials.
• The figure number and title in the List of Figures should be the same as the number and title in the body of the report.
• Each figure should be described and referenced in the text so that the reader knows to look for the illustration.
• A figure should follow the paragraph in which it is first mentioned (same or next page).
• Horizontal figures should be put in the report so that the top of the drawing is on the left and the bottom is on the right. Be careful that the margins are wide enough that the entire figure, including its title, is visible when the report is bound.

4) Executive Summary (1 – 1 ½ pgs only)
   a) Problem Statement
   b) Discuss the design process
   c) What was the final design
   d) How well did the final design work (including where your roller coaster lost more energy than expected)
   e) What could have been done to improve the performance

5) Introduction
   a) Problem Statement
   b) Organization of the Report
This part of the report has three main purposes. First, it tells the reader exactly what problem is being solved or what piece (or pieces) of equipment will be designed. Next, it explains to the reader why this work is important. Finally, the last paragraph of the introduction gives the reader a "road map" to the report by describing the organization of the report. For example, the last paragraph might contain sentences such as, "Section 2 contains the requirements and constraints the design must meet." or "Description of the preliminary paper design is presented in Section 3."

NOTE: Very few people read a report from cover to cover. They scan the introduction to see whether the project being described is of interest to them. If it is of interest, they might check the "Organization of the Report" to see which section will provide the information they are seeking.
6) Requirements, Constraints, and Information Needs
How does the sponsor, i.e., the person who paid for the project, decide whether the design is acceptable? He or she makes that decision by determining whether the product meets all of the requirements and can be produced within the constraints. This section describes the requirements and constraints that will be used to judge the design. In it team members also identify any additional information they will need to gather in order to design an acceptable product. Examples of a requirement, a constraint, and information need follow.

- **Requirements**: specific features that the design must have
- **Constraints**: factors that limit design options
- **Information needs**: data that must be collected to evaluate proposed designs

**Example:**
Suppose a team is to design a child's car seat that converts into a stroller. A requirement might be that the seat be light enough for one person to lift easily. However, a constraint, at least here in Ohio, is the law that any child weighing 45 pounds or less must be in a car seat while traveling in an automobile. The car seat must, therefore, be strong enough to support a 45-pound child, and that certainly could affect the weight of the car seat. As a result, two information needs might be the density and strength of a variety of materials that could be used in a car seat.

7) Paper Design Concepts and Analysis
The reader will turn to this part of the report to learn about the team's preliminary paper design. Some readers will learn more by reading a written description, some will prefer an illustration, and still others will use both. Thus the team must provide a clear written description and illustration of the concept and a link between the text and the illustration.

The team reports on the paper design and the actual design progression, in light of the requirements and constraints, and on its final design decision. The reader should be able to follow the team's reasoning as it accepts or rejects all or parts of each concept and selects a final design. In addition, the team will describe any refinements to the design (include all relevant revisions to illustrations) and the reasons for them. All calculations (including MATLAB, Excel and paper-based calculations) should be presented.

**Hints**
- Think of the written description of as what a team member might say in a telephone conversation with a potential customer who has asked for a description of the design. The goal is to paint a "mental picture" of the concept.
- The concept should be described in detail.
- Stick to the facts. This is not an advertisement. It is a formal, professional report.
- Include illustrations of the concept as and when needed.
- Refer to the illustration in the text so that the reader knows the illustration is available. Here are some examples of references to an illustration: "The three-wheeled stroller, shown in Figure 3.5, is..." or "One unique feature of this concept is the detachable canopy. (See Figure 3.7)"
- Illustrations should follow the paragraph in which they are first mentioned, if the illustrations occupy less than a full page. If an illustration requires a full page, it should be on the page following the one in which it is first mentioned.
• Each illustration (figure) should have a number and a title. For example, “Figure 3.5. Three-Wheeled Stroller/Car Seat Combination in Stroller Mode.”

8) Final Design Description, Drawing and Analysis
If the reader turns to this section first, he or she should find a written description of the final design that provides a clear "mental picture" of the design. That description should be followed by hand drawn orthographic/isometric drawings of the complete final Roller Coaster Design. This section should include:
   a) Introduction to the section
   b) Description of the final design
   c) Summarize the paper and actual design progressions
      i) Submit energy analysis spreadsheets (one spreadsheet per feature) for at least first five features
      ii) Create table summarizing the expected velocities and energy loss values while going in and coming out for all the features (refer to the table submitted in the initial paper design, update that table with the final design features).
   d) If you use hand sketch for the three orthographic views with full dimensions and one isometric view, you are required to assemble one feature (vertical loop, horizontal loop, bump, etc.) of your final coaster using the parts in SolidWorks.
   e) EXTRA CREDIT: A complete set of three orthographic views and one isometric view of the final coaster in SolidWorks is worth 30 additional points to the Final Report. Note: the coaster must include all PVC supports, the tower, and the track.

9) Speed Sensors
In this section, you should discuss where you located the speed sensors and the reasons for these locations. This section should foreshadow the discussion under Performance Analysis.

10) Performance Analysis
This is the section for the reader who simply wants to know the "bottom line" - what happened in the competition, why it happened, and what the team learned from the design project experience.
   • Tell the reader how your team's system performed (sometimes a table of data with a discussion of the most important information in the table is effective).
   • Discussion on the performance of the team's design in the final test; identify the tasks your system performed as expected and mention any problems encountered.
   • Be sure to discuss why the problems occurred and what could be done to solve them. It is very important to include discussions of the velocities you obtained from the speed sensors and to have identified where the key differences occurred between the spreadsheet calculations and your actual experience. In light of this use the velocities from the speed sensors, to create a table comparing the actual v.s. expected values and based on this comparison answer the following questions
      o How did the velocity you measured at the top of a loop compare with \((gr)^{1/2}\)?
      o How did the velocity you measured at the top of a bump compare with \((gr)^{1/2}\)?
      o How did the velocity at the end of the coaster compare with what you calculated for your final design?
What was the average velocity of the ball for your coaster? (Hint: use the time between the 1st and last velocity measurements and the length of the track.)

- Plot the experimental and theoretical velocity v.s. track distance from final RC test. The experimental velocities are read through the speed sensor data whereas the velocity values from the energy analysis spreadsheet constitute the theoretical velocities.
- Based on the plot obtained in the previous step, document the difference between the experimental and theoretical velocity values by identifying the coaster features where the two sets of velocities have maximum and minimum difference. By analyzing your design, justify the reason behind the coincidence and variation of these velocities at different track sections.

### 11) Summary & Conclusions
Finally, in a paragraph or two summarize what the team learned from the design project. The "lessons learned" could be related to technical components of the system, communications skills, teamwork, or any other aspect of the course. Include things you will want to remember to do in the future as well as things you want to avoid.

### General Tips:
Some tips on report preparation could apply to more than one part of the report:

- The report is a formal, professional document. It is not advertising copy. Use formal language. Choose words carefully. Be accurate. Do not exaggerate.
- The audience for this report is a group of engineers and their managers who must first decide (on the basis of the written report) whether your design is the best one for their needs. Then, if it is the best, they must be able to build your design using only the information provided from your report.
- Don't use first person (I, me, my, we, our) or second person (you, your). Refer to the writers of the report as "the team", "team members", etc. Sometimes, it may be necessary to use passive voice to avoid using first person.
- Provide as much detail as is necessary to describe the project but be as concise as possible. Be considerate of the reader. Don't waste his or her time. If a word doesn't provide new or important information, leave it out.
- Use 1 1/2 or double line spacing.
- Number the pages. The Title of Contents is on page "i", the List of Figures is on page "ii", and the first section "Introduction" begins on page 1.
- Use headings and subheadings to help the reader follow the organization of the report or find the section of interest. Section titles should be the same as those in the Table of Contents. If a numbering system is used for headings and subheadings, it should be the same as the one in the Table of Contents.
- Every section, with the exception of the introductory section, should begin with an introduction that tells the reader what is contained in that section. Remember, the reader may have turned to this section without reading earlier parts of the report.

### 12) References (Optional) – remember to identify the source of all information from other documents directly used in this document.
Final Report GRADING GUIDELINES

DOCUMENT GRADED: FINAL REPORT

TEAM DESIGNATION: ______________________

<table>
<thead>
<tr>
<th>ITEM</th>
<th>POSSIBLE POINTS</th>
<th>POINTS EARNED</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVER PAGE</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>LIST OF FIGURES &amp; TABLES</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>MAIN BODY: CONTENT</td>
<td>76</td>
<td></td>
</tr>
</tbody>
</table>

The following non-gray cells represent the breakdown of the 70 points allotted for MAIN BODY: CONTENT. Bolded lines are sections of your report. Non-bolded lines are requirements within that section.

- **Requirements, Constraints & Information Needs** 5
- **Paper Design Concepts and Analysis** 8
- **Final Design: Description** 8
- **CAD/other Drawings of Final Design** 20
- **Final Design Analysis: 1a.** Show design calculations for at least one feature (5 pts). **1b.** Submit energy analysis spreadsheet for at least first five features (5pts) 2. Table summarizing velocity and energy loss values for all features (5 pts) **3.** Brief justification of Final Design (2 pts) 17
- **Speed Sensor Section** 5
- **Performance Analysis** 13
- **SUMMARY & CONCLUSIONS** 5
- **TOTAL POINTS** 100
ORAL PRESENTATION

Oral Presentation Details

**Dress:**  Business casual (Shirt/ polo, pleated trousers/ khakis, formal shoes, Tie (optional))

**Time Allowed:**  8 minutes for presentation, with 2 minute for questions and answers

Content of Presentation:

- This should be a concise oral presentation of the most important points made in your written report with a concentration on the design process for your coaster, your final design, the performance of your coaster, and what you learned from the experience (your summary and conclusions).
- Make sure to discuss your brainstorming ideas, why you picked the features for your initial design, and how the initial design evolved into your final design.
- Do NOT discuss the roller coaster specifications!!  These were given to you and are the same for every team. Only refer to the document where the specifications are located.
- For more information on point distribution, please refer to the Presentation evaluation form.
- More time should be spent on those areas where points are most concentrated.
- Use PowerPoint for your presentation
- **Upload the final version of your PowerPoint presentation to Carmen Dropbox AT LEAST 24 hours before the lab. Bring your own copy for backup!**

Oral Presentation Outline and Draft

For the **OUTLINE**, you are required to provide the following in a [MS WORD document]:
- Show the organization of your presentation material
- The order in which the team members are planning to present the material
- Time allotted to each topic of presentation

For the **DRAFT**, you are required to provide [MS PowerPoint slides]. You will be graded on the following:
- Completeness of the slides – You are expected to have completed a major portion of the slide preparation in this draft
- Font size
- Color and type of slide
- Font-slide contrast – If the color of the font and the background slide chosen helps/hinders visibility of the presentation material
- Avoid full/long sentences in slides
- Figures and tables encouraged
<table>
<thead>
<tr>
<th>General Quality of Presentation</th>
<th>Individual Team Members:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Poise / professionalism (Appropriate attire, posture, gestures, etc.)</td>
<td>0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10</td>
</tr>
<tr>
<td>2 Delivery (Eye contact, voice level/inflections, rate of speech, enthusiasm, etc.)</td>
<td>0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10</td>
</tr>
<tr>
<td>3 Main points of presentation clear (Understanding of topic, emphasis on relevant items, etc.)</td>
<td>0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10 0 2 4 6 8 10</td>
</tr>
<tr>
<td>TOTAL POINTS (30 max):</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content (Team Score)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Introduction of team members</td>
<td>0 1 2 3 4 5</td>
</tr>
<tr>
<td>2 Overview of presentation</td>
<td>0 1 2 3 4 5</td>
</tr>
<tr>
<td>3 Description of brainstorming ideas</td>
<td>0 1 2 3 4 5</td>
</tr>
<tr>
<td>4 Brief description and analysis of initial paper design</td>
<td>0 1 2 3 4 5</td>
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<tr>
<td>5 Revisions and detailed description of final design</td>
<td>0 2 4 6 8 10</td>
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<tr>
<td>6 Performance analysis of final system test (Results of final test in addition to velocity analysis)</td>
<td>0 2 4 6 8 10</td>
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<tr>
<td>7 Discussion of major design problems and solutions (Problematic coaster feature or significant design changes)</td>
<td>0 2 4 6 8 10</td>
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<tr>
<td>8 Summary / Conclusion</td>
<td>0 1 2 3 4 5</td>
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<tr>
<td>9 Overall slide quality / readability / effectiveness</td>
<td>0 1 2 3 4 5</td>
</tr>
<tr>
<td>10 Team stayed within allotted time</td>
<td>0 1 2 3 4 5</td>
</tr>
<tr>
<td>11 Questions answered clearly</td>
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</tr>
<tr>
<td>TOTAL POINTS (70 max):</td>
<td></td>
</tr>
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Comments:  

Additional Comments on Back of Sheet