ESC204
Project Guideline

THE AUTONOMOUS ELECTRIC CAR CHARGING SOLUTION

WINTER 2020

UNIVERSITY OF TORONTO | ENGINEERING SCIENCE

TABLE OF CONTENTS

1 INTRODUCTION

This project is designed to provide the students experience with designing mechatronics system through designing and building an autonomous solution *(no human control/interaction)* for plugging in an electric car charger.

1.1 TEAM FORMATION

You are expected to form your own team of **three (3)** members to work on this design project. All of your team members must be enrolled in and attend the same practical session through the entire semester. You should also work with your project team during workshops starting from the second mandatory workshop (January 10th).

Individuals are not assigned specific roles during the project. However, in general, groups composed of members that cover the following specialties/interests usually demonstrate outstanding performance in concept delivery, design and build:

- Programming
- Electrical design
- Mechanical design
- Project management
- Presentation/writing

Please enroll in the same group with your team members on Quercus Group Page by **22:00 on Thursday, January 9th (2020-01-09).** Please make sure your team **enrolls in a group based on your practical session**. If you are in Monday practical session, enroll in a group starting with M (M01 – M28), for Tuesday practical session, enroll in a group starting with T (T01 – T28), for Wednesday practical session, enroll in a group starting with W (W01 – W28).

If you are not enrolled in any group by the group enrollment deadline, **you will be randomly assigned a team.**

1.2 SAFETY

You **MUST** complete the Myhal Light Fabrication Facility (MYLFF) safety training. This includes two online training module and an in-person training. You are expected to follow the safety rules when working either inside or outside of the MYLFF.

2 Project Description

2.1 Project Requirements

You are required to design a solution that could accurately plug in an electric car charger into a charging port. The testing environment is setup to simulate an electric car parked in the garage by a driver, the charging port position could thus be anywhere within a 0.5m x 1m rectangle, facing at any slight angle.

Your design is allowed to be set up initially in a 1.5m x 2m rectangle, before the test fixture (the car) arrives in the charge port zone, as shown in *Figure 1*. Your design is required to locate the charge port and plug in the charger plug autonomously within a 2 minutes testing time.

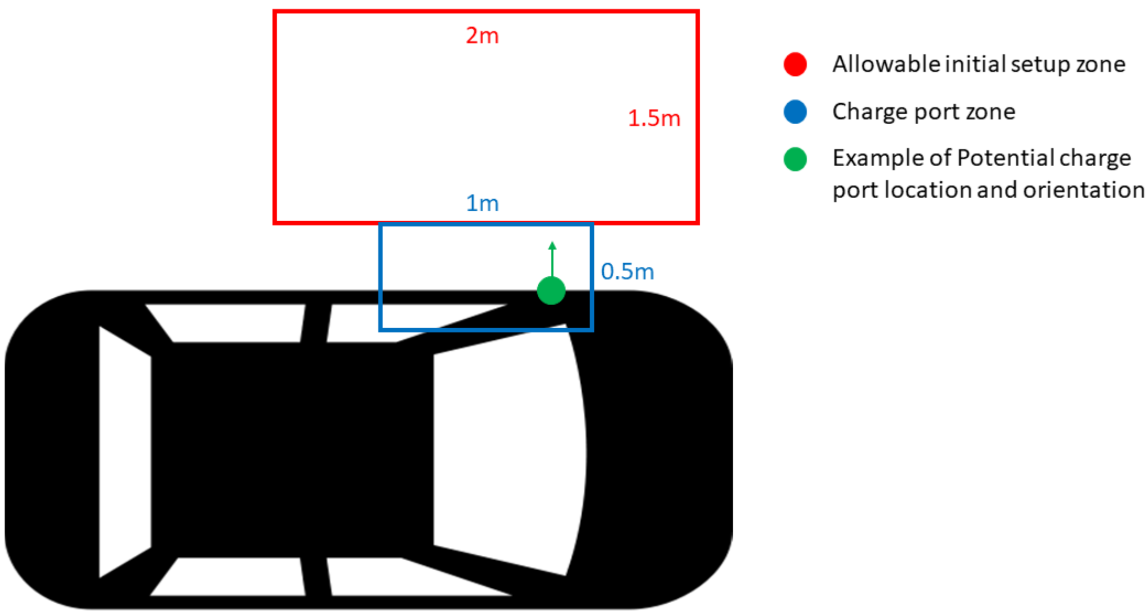

Figure 1 - Example Setup

2.2 Testing Setup

2.2.1 Test Fixture Setup

The test fixture setup is designed to simulate an SAE J1772 Type 1 charger charging port (referred as "the charging port").

The .step file for the test fixture assembly is available on Quercus.

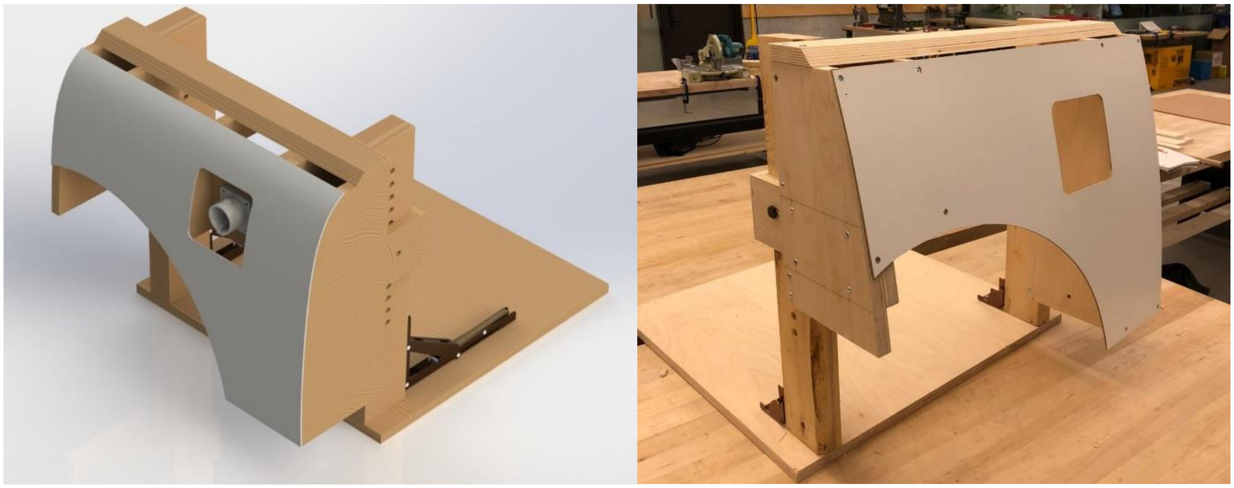

Figure 2 - Test Fixture

A few important dimensions of the test fixture are shown below:

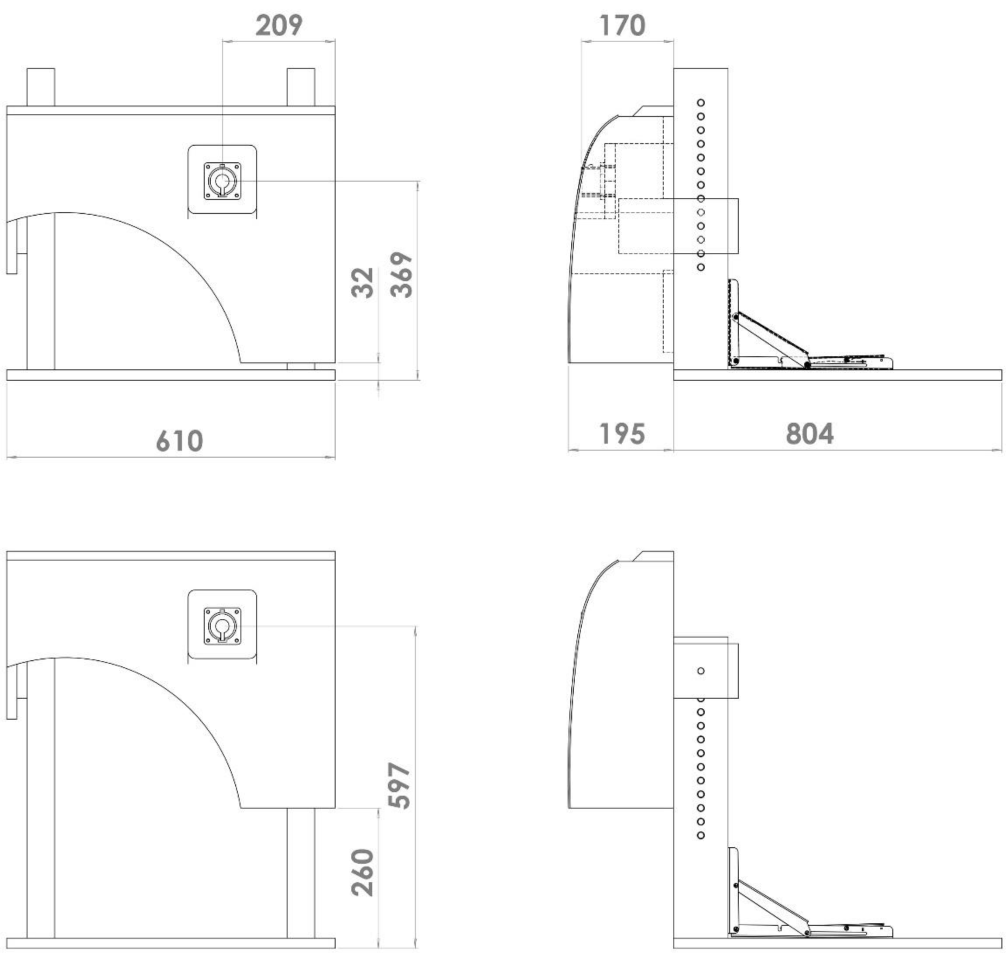

Figure 3 - Test Fixture - (Top) Lowest Z-Axis, (Bottom) Highest Z-Axis
(dimensions in mm, subject to fabrication tolerances)

The charge port used for testing is a 3D printed design:

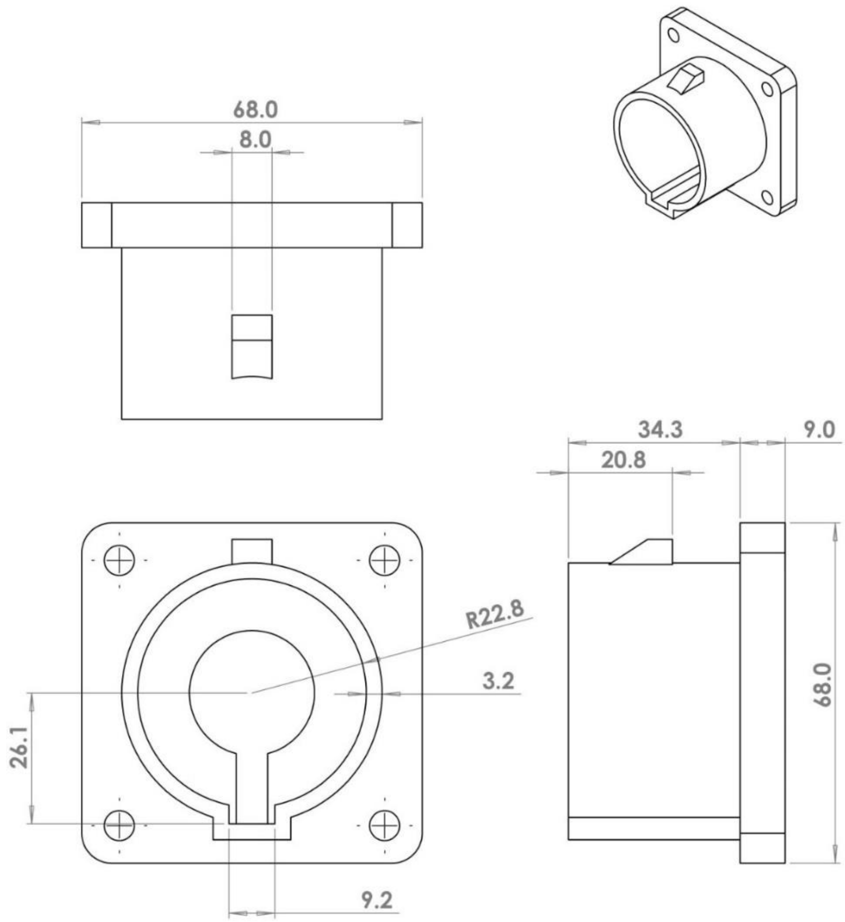

Figure 4 - 3D Printed Charge Port
(dimensions in mm, subject to 3D printing tolerances)

Figure 5 - 3D Printed Charge Port on the Test Fixture

2.2.2 Charger Plug Setup

For simplicity, the cable of the charger plug will be removed for testing.

The testing charger plug is designed to simulate a SAE J1772 (IEC 62196-1 Type 1)[1] charger (referred as "the charger plug" in the future part of the document).

Figure 6 - SAE J1772 (IEC 62196-1 Type 1) Charger

There are three types of charger plugs available for testing: 3D printed dummy without alignment tab, 3D printed dummy with alignment tab, and off-the-shelf plug. These are associated with different difficulty levels that will be explained in detail in later sections.

Comparing with the off-the-shelf real plug, the 3D printed dummies have the same general geometry, with the spring-loaded locking tab eliminated, and weighs less.

A few important dimensions of the 3D printed dummy plug are shown below:

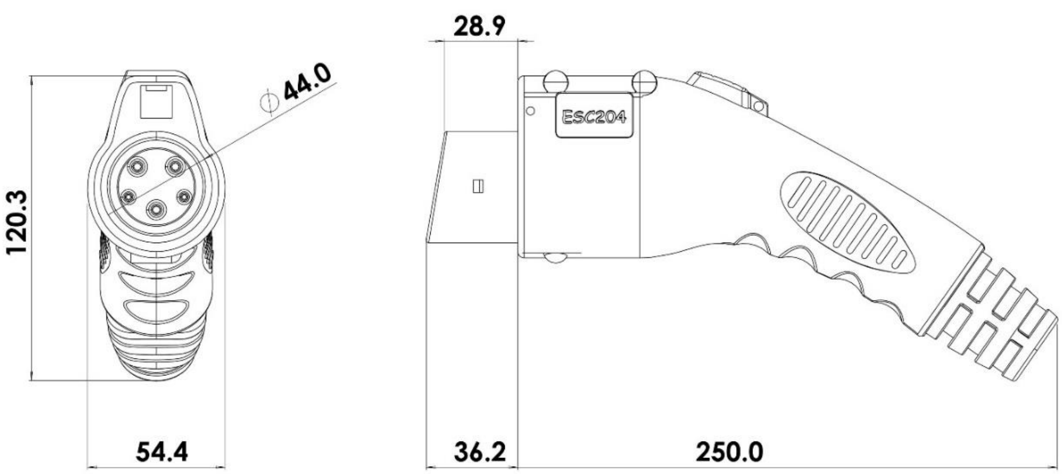

Figure 7 - 3D Printed Dummy Charger Plug without Alignment Tab
(dimensions in mm, subject to 3D printing tolerances)

[1] IEC 62196-1:2003

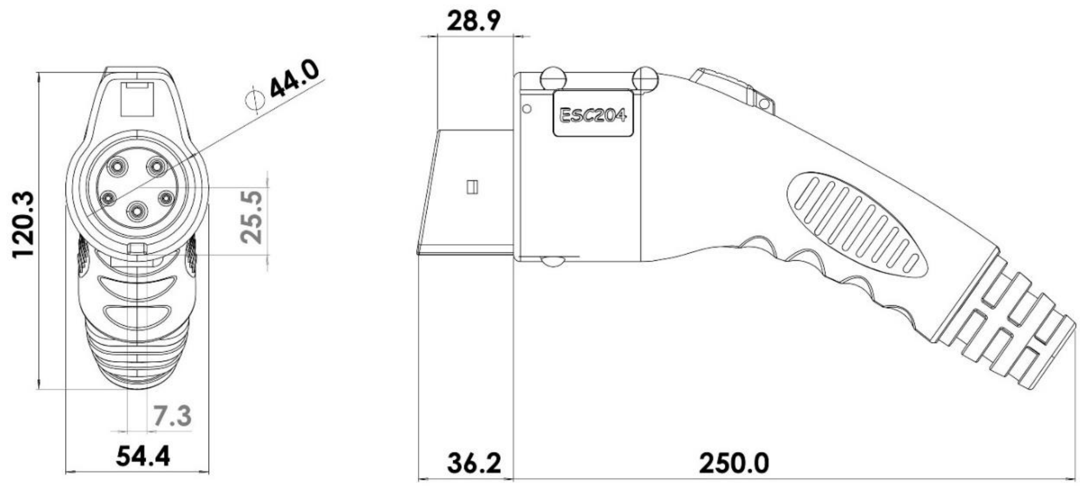

Figure 8 - 3D Printed Dummy Charger Plug with Alignment Tab (dimensions in mm, subject to 3D printing tolerances)

Figure 9 - 3D Printed Dummy Charger Plug with Alignment Tab

You will have access to the 3D printed charge ports and plugs from MYLFF for taking measurements and testing. You can check out a pair with your team number during your practical sessions or outside of class hours, but you are not allowed to take them out from the MYLFF space.

The .step files for all types of the charger plugs and the 3D printed charge port are available on Quercus.

2.3 OBJECTIVES

2.3.1 Aspirational Objectives

1. Engage in appropriate design processes towards development of a mechatronics system to address a real-world need.
2. Understand and apply mechanical, electrical and programming knowledge learned in previous courses in developing a solution for a real-world engineering problem.

3. Breakdown an engineering problem into smaller testing goals and integrate testing goals in the final design.
4. Review and consider all available resources for alternative design solutions.
5. Source and acquire materials for prototype development.
6. Gain competence using rapid prototyping tools (computer aided design, 3D printers, laser cutters, etc.) to fabricate, integrate, and debug mechatronics systems.
7. Systematically evaluate the trade-offs between various system requirement, materials and technologies.
8. Communicate and collaborate efficiently as a team.
9. Develop habits and systems to document design, build and test processes for projects.
10. Prepare written proposals, documentation and oral presentations.

2.3.2 Operational Objectives

1. Develop and construct a design that achieves the following major functionalities:
    a. Locating the charge port
    b. Delivering the plug to the charge port
    c. Inserting the plug into the charge port[2]

2. The design should demonstrate[3] **at least five (≥5)** of the following DfX principles deliberately:
    a. Design for Appearance & Style
    b. Design for (Ease of) Assembly
    c. Design for (Low) Cost
    d. Design for the Environment
    e. Design for Manufacturing
    f. Design for Modularity
    g. Design for Power Efficiency
    h. Design for Reliability
    i. Design for Safety
    j. Design for Serviceability & Reparability
    k. Design for Standards
    l. Design for Testing & Diagnostic
    m. Design for Usability

3. The design should be able to achieve the functionalities under the following settings (referred as "**baseline setting**"):
    a. Charger plug: 3D printed dummy without alignment tab (*Figure 7*) for testing purposes
    b. Charge port location:
        - At known X-axis position (0 m ± 0.05m)[4]
        - At known Y-axis position (0.25 m ± 0.01m)

[2] This task is successful only when the plug is fully inserted, and the spring-loaded clip is engaged (for additional setting A2)
[3] Provide sufficient documentation to support your arguments. You will be evaluated through all the written reports, progress check-ins, and final milestone. More details will be posted in each deliverable document.
[4] Tolerances on X, Y positions are added to account for human errors from manual placement of the test fixture

- At known height (0.37 m)
- At known angle (0° between the port and the Y axis)

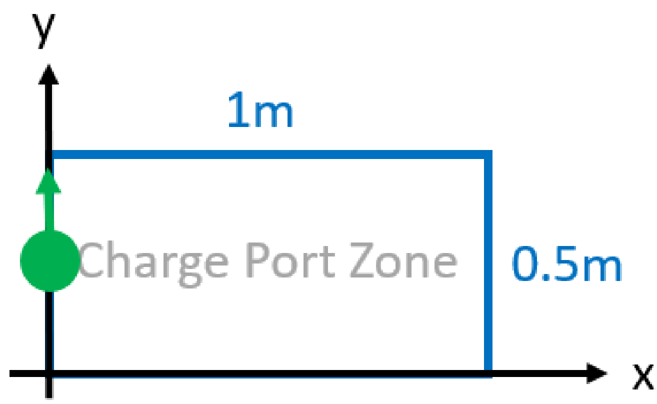

Figure 10 - Charge Port Location and Orientation in Baseline Setting (0, 0.25, 0.37[5] , 0)

4. **(Team Goal)** For the **final milestone**, the design should be able to adapt to **more than one (>1)** additional settings/tasks that your team chooses:
   a. **(Additional setting A1)** Charger plug: 3D printed dummy with alignment tab (*Figure 8, Figure 9*)
   b. **(Additional setting A2)** Charger plug: J1772 charger plug with spring loaded clip (real off-the-shelf J1772 charger plug)[6]
   c. **(Additional task B)** Retract charger plug: After plugging in, wait for **at least five (≥5)** seconds, retract the plug from the charge port, then return to a repeatable start location[7]
   d. **(Additional setting C)** Charge port location (Defined by Degrees of Freedom, each DoF counts as one additional setting):
      - **(1DoF - X)** At a random position on the X-Axis between (0, 1) m
      - **(1DoF - Y)** At a random position on the Y-Axis between (0, 0.5) m
      - **(1DoF - Z)** The center of the charge port at a random height from the ground, between (0.37, 0.60) m
      - **(1DoF - Yaw)** Facing a random angle between the port and the Y axis, between (-45°, 45°)

[5] Z Axis height not represented
[6] The off-the-shelf charger plug has the same geometries as the 3D printed one, but is heavier, and has a spring-loaded locking clip. You will also be able to borrow them from the MYLFF but there is very limited quantity.
[7] "A repeatable start location" is any location where your design is able to repeat the entire operation without need of human assistance. If your design requires initial alignment, then it must return precisely to the original start location. If your design functions from an arbitrary start location, then it only needs to return to the setup zone.

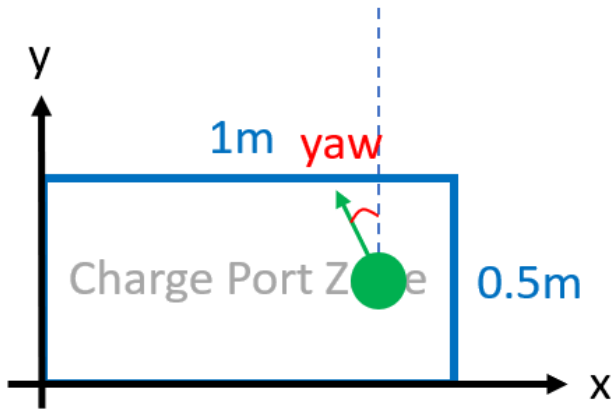

Figure 11 - Example Setup of Charge Port Location and Orientation (0.8, 0.25, Unknown, -30)

2.4 CONSTRAINTS

2.4.1 Budgetary

- **ALL** components in the final product must cost **less (<)** than **$300**[8]
  - For purchasing made through MYLFF, the components cost should be based on the listed price from MYLFF
  - For purchasing made outside of MYLFF, the components cost should be based on the purchasing price, **keep** digital copy of the purchasing receipt for potential audit
  - Only raw materials cost should be considered for 3D printed/laser cut components

2.4.2 Logistics

- The initial setup time of the design must be within **three (3)** minutes.
- The design must be able to perform the task within **two (2)** minutes.
- The design must be able to display a visual or audio signal once it achieves the following:
  - Locates the charge port
  - Plugs in the charger plug
- The time it takes to remove any setup in the environment after testing must be less than **one (1)** minute.
- The design must be setup before the setup of the test fixture.
- The workshop rover must not be used directly for milestone testing.
- The design must not use pre-designed commercial products to achieve specific functions, either assembled or in kit form[9]

2.4.3 Mechanical

- The initial design setup (other than the external power supply, if applies) must be within a **1.5m x 2m** range, as shown in *Figure 1.*

---

[8] Another team must be able to fully replicate your design with components they just bought, in under $300.
[9] For example, you can not purchase a robotics arm and integrate it in your design. It is acceptable to use commercially available components like Arduino, Raspberry Pi, etc.

- Any setup on the environment (not part of your design, i.e. charge port, ground, etc.) must be easily removable without any residue.
- The design must not physically damage the test rig during setup or operation.
- The design must not use compressed air for actuation.
- The charger plug could be mounted on the rover by human, however it must be removeable from the design by a user quickly (i.e. it must not be glued or taped in place).

2.4.4 Electrical

- All control and actuation voltage must be no more than **24Vdc** nominal (Nominal voltage of battery or power supply).
- All external power supply that connects to a wall outlet must be UL, CSA approved[10].
- There must be a distinct way to command the design to start (i.e. a physical start button, sending remote command, plugging in power).
- The design must have an emergency stop button or switch that stops all actuators.
- Power can be derived from an onboard battery or an external power supply.
- High voltage contacts must not be exposed to a human in any way (Fully shielded and grounded box is ok, uncovered terminal blocks with mains voltage is not).
- No **hazardous** radiation shall be emitted, electromagnetic or otherwise.
- No unnecessarily loud sounds or bright lights allowed.

3 DELIVERABLES AND EVALUATION

3.1 DELIVERABLES OVERVIEW

For each deliverable, more detailed guideline and rubrics will be posted.

Table 1 - Deliverable Overview

Deliverable	Time	Weight	Content
Design Concepts and Project Plan	Week 5 (during Practical)	10%	Informal presentation
Project Proposal	Due 2020-02-23	10%	Written design proposal with detailed design
Milestone 1 Progress Evaluation	Week 9 (during Practical)	7.5%	Milestone performance - Mobility
		2.5%	Progress check in with TA
Milestone 2 Progress Evaluation	Week 10 (during Practical)	7.5%	Milestone performance – Locating
		2.5%	Progress check in with TA
Milestone 3 (Final) Design Competition	Week 12 (during Practical)	20%	Milestone performance - Integration
		5%	Evaluation of DfX Principles

[10] Per University of Toronto Building Standards

Final Deliverable	Week 13	20%	Written final report and individual contribution review
Final Video Presentation	Week 13	5%	Video presentation

3.2 Milestone Logistics

For each milestone, each team will be given **two (2)** opportunities to complete the task(s) and the higher grade from the two trials will be recorded as your final grade. There will be **two (2)** hours in between your two trials for you to make any improvements/adjustments to your design.

The first two milestones are rather simple and designed to be opportunities to provide you with feedback and keep your timeline on track. While working towards performing milestone 1 & 2 tasks, you should also work towards the long-term team goal for the final milestone.

For **milestone 1**, the design should demonstrate ability to deliver the charger plug from the initial setup area to the charge port at a given location and perform an inserting action. The design could incorporate remote control for this milestone.

For **milestone 2**, the design should demonstrate ability to autonomously locate the charge port accurately at a given rough location and provide an indication by delivering an end-effector to the front of the charge port. The location of the charge port will be given prior to the test with tolerance from section 2.3.2.

For **milestone 3 (final milestone)**, the design should integrate all of the functionality to autonomously perform all the tasks from section 2.3.2-1. Your performance will be graded based on the achievement of the tasks, additional settings (2.3.2-3), ~~and the time it takes to perform the tasks~~. Detailed marking rubrics with points breakdown is posted in a separate document.

Successful achievement of all the tasks (2.3.2-1) under the baseline setting (2.3.2-2) will receive 70% of the grade. For each additional setting or task (2.3.2-3) that your team choose, you receive another 5%[11] upon successful completion of the tasks under the setup.

For each milestone 3 trial, the team will be given **ten (10)** minutes in total. You can start with the difficulty setting of your choice (i.e. baseline setting). Upon successful completion of the tasks, your corresponding grade will be recorded. Within the permitted time, you will have the chance of performing more runs either with the same difficulty or with raised difficulty by applying the selected additional settings. Your grade for this trial will be the highest amongst all the runs.

[11] The maximum achievable grade for milestone 3 is 70% + 7*5% = 105%. However, the maximum course grade contribution from any deliverable is capped by its weight assigned (Table 1). A team completing anything higher than 100% will receive 100%.

For example, a team choose to start with the baseline settings, complete the tasks, receives 70%. Within the time limits, raise the difficulty by having 2 degrees of freedom for the charge port, complete the tasks, receives 90%. Raise the difficulty again by having 3 degrees of freedom for the charge port, failed to complete the task. The team will receive 90% for this trial.

During a milestone 3 run for a team, the logistics will be as follows:

- The team sets up the design
- A member of the teaching team moves the test fixture to a location/height based on the difficulty chosen, record the location
- The team initiates the run through an action (i.e. a physical start button, sending remote command, plugging in power)
- The design performs its tasks autonomously
- Repeat and adjust parameters if needed within time limits

4 Project Resources

4.1 Workshops

Upon the successful completion of the first 4 weeks of workshop sessions, you are expected to be familiar with the following concepts and skills that can be directly applied to building a prototype:

- Mechanical design & light fabrication (CAD, hand tools, 3D printing, laser cutting)
- Electrical design & fabrication (circuit design, soldering, troubleshooting)
- Input/output integration & calibration (Digital and analog interfacing with sensors and actuators)
- Microcontroller programming

4.2 Budget

You are allowed to purchase materials from or outside of the MYLFF. A list of available materials through the MYLFF will be posted.

MYLFF will use your team number to keep track of the materials you have purchased throughout the semester. You will be responsible to pay off the MYLFF bill with your T-card. You are allowed to spend up to **$330 per team** with the MYLFF. As the MYLFF materials price are reasonably low, there will not be any reimbursement for any additional purchases. More details on the purchasing logistics will be posted later.

4.3 Myhal Light Fabrication Facility

Materials and Tools

Upon completion of the safety training with the Myhal Light Fabrication Facility (MYLFF), you will gain access to the space, tools, and materials purchasing. During the time of your practical sessions, you will be given priority for the usage of the space and tools. Share the space respectfully with other students from other courses outside of the class hours.

MYLFF opening hours during the school year:

- Monday – Thursday: 0900 – 2130
- Friday: 0900 – 1800
- Saturday: Closed
- Sunday: 1000 – 1800

Storage space

You can **request** for a locker for materials/design storage throughout this semester from the MYLFF. Information of the lockers including **dimensions** and **how to request** them can be found: https://utoronto.sharepoint.com/sites/fase-myhalfabrication/SitePages/Locker-page.aspx

Please keep in mind that the course could not provide additional storage space other than the rental lockers. Although there are no dimensional or weight constraints for your design, you should consider your design dimensions and/or design for assembly/disassembly, if you wish to rent and use a locker.

Common sense should also apply to the design dimensions (e.g. your design should fit through a door).