ENGINEERING

McMaster University

Project Three – There's a Recyclable Among Us:

Design a System for Sorting and Recycling Containers

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 5

Team 24

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Zhenyu Zhao (zhaoz154)

Amir Rayyan Khan (khana344)

Ehsaan Khan (khane16)

Submitted: March 6, 2021

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Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Borna Sadeghi 400315188

x 

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Ehsaan Khan Click or tap here to enter text.

x E.K.

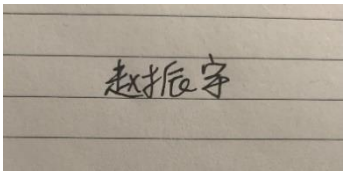
The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Amir Rayyan Khan 400327655 Click or tap here to enter text.

x 

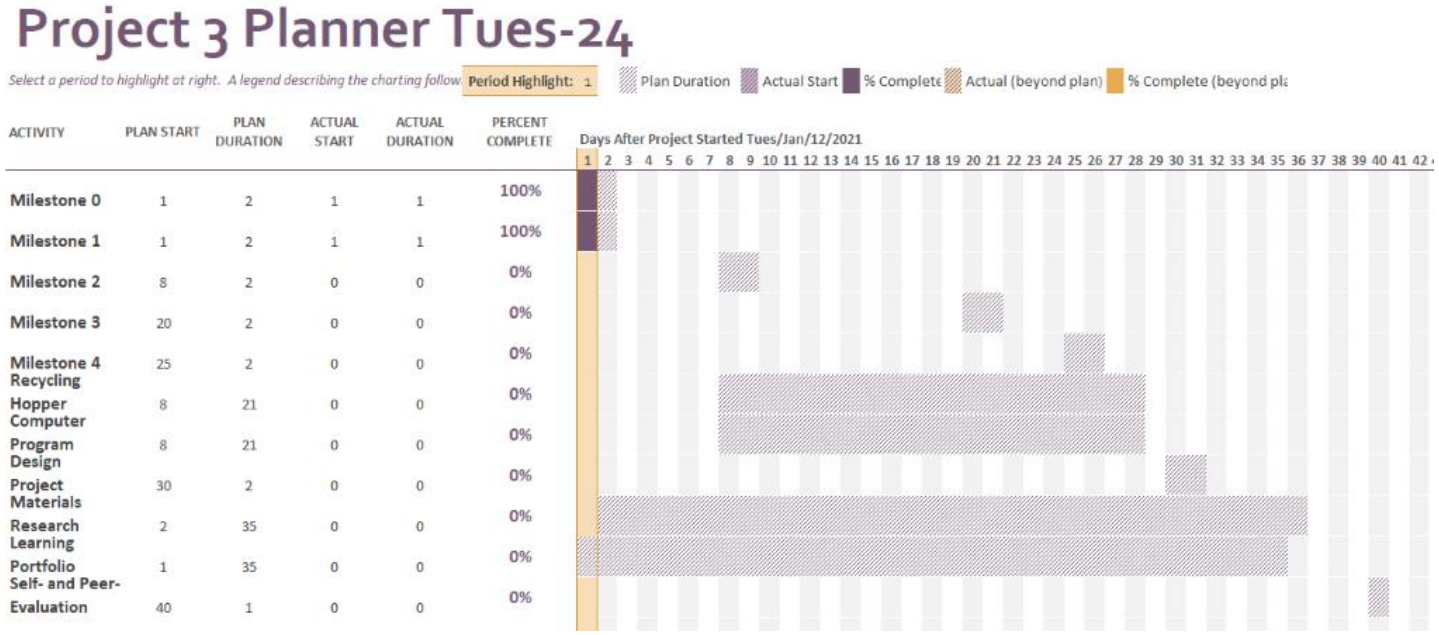
The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Zhenyu Zhao 400305220

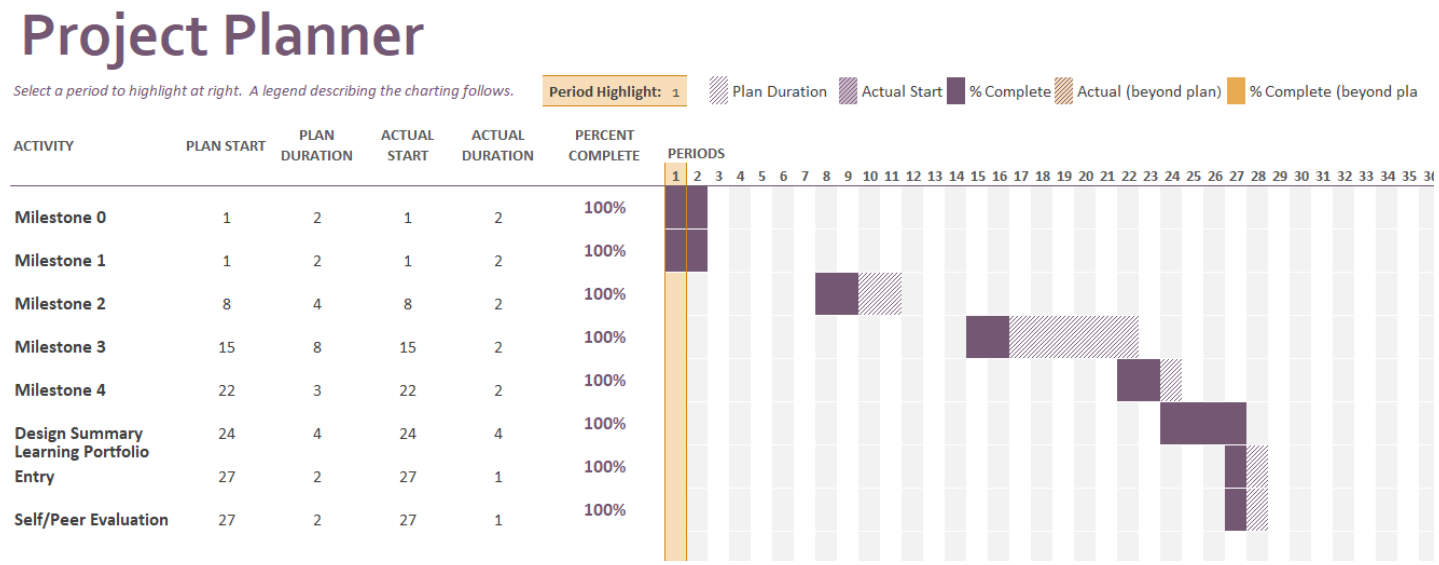


Project Schedule

Initial Gantt Chart



Final Gantt Chart



Executive Summary

The motivation for this project is derived from raised concerns regarding recycling processes. Being thrown in the recycling bin is not sufficient for a product at end-of-life to be recycled; in fact, only about 70% of items put in recycling bins are actually recyclable [2]. And in Canada, for plastics that are recyclable, only about 9% are actually recycled, with the rest incinerated or placed in landfills [2]. Under such conditions, the demand for efficient recycling process has raised to a significant level in our society. The modelling subteam decided to create a simple mechanical system contain three components: linear actuator, a connecting part and a modified hopper. The general working principle of the system is that we connect the linear actuator and the hopper with a connecting part which has has two holes at two tips. When the linear actuator pushes out as a output, the ending of connecting prat which was connected with the hopper would lift up and support the hopper up as well. In order to get to this solution, we first modified the size of hopper in order to allow the hopper to fit between the base plate and the actuator. Then we created a joint at the bottom of the hopper so that when it is connected with the connecting part, an angle can be generated, which simplify the procedure of lifting. At the end, we found that the angle lifted is not satisfying so we decided to cut the front face of the hopper in half so that the container can fill out the hopper easily. The computing subteam focused on programming three main components: the servo table, Q-arm, and Q-bot, all simulated in the Quanser virtual environment. Firstly, the servo table classifies containers and determines which ones should be picked up by the Q-arm next. We used the following algorithm to optimize the process and load the Q-bot as fast as possible. First, fill in all the empty container slots on the table. Then, classify each container by their target bin. The most frequently occurring target bin among all containers determines which containers to pick up next. By doing this, it is certain that there will be at least two containers that could be put in the hopper at once, increasing efficiency. The Q-arm picked up containers on queue when the table has moved the container in place, and put them in appropriate positions on the Q-bot hopper to minimize the chances of them falling over. The Q-bot was tasked with moving towards an array of bins, and dumping the containers into the bin specified by the servo table before turning around and repeating the process. It knows where the bins are by using an ultrasonic sensor that determines the distance from the correct bin, and dumping the containers when it drops below a certain threshold.

Reference:

[2] "What Goes in the Blue Bin (Recycling)?," City of Toronto, 23-Dec-2020. [Online]. Available: https://www.toronto.ca/services-payments/recycling-organics-garbage/houses/what-goes-in-my-blue-bin/. [Accessed: 03-Mar-2021]

[3] "Canada recycles just 9 per cent of its plastics," Recycling Council of Ontario, 06-Dec-2019. [Online]. Available: https://rco.on.ca/canada-recycles-just-9-per-cent-of-its-plastics/. [Accessed: 03-Mar-2021]

- （modeling）For modeling, we decided to create a simple mechanical system contain three components: linear actuator, a connecting part and a modified hopper. The general working principle of the system is that we connect the linear actuator and the hopper with a connecting part which has has two holes at two tips. When the linear actuator pushes out as a output, the ending of connecting prat which was connected with the hopper would lift up and support the hopper up as well. In order to get to this solution, we first modified the size of hopper in order to allow the hopper to fit between the base plate and the actuator. Then we created a joint at the bottom of the hopper so that when it is connected with the connecting part, an angle can be generated, which simplify the procedure of lifting. At the end, we found that the angle lifted is not satisfying so we decided to cut the front face of the hopper in half so that the container can fill out the hopper easily.

Scheduled Weekly Meetings

Milestone 0&1 Meeting Minutes

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Ehsaan Khan**	**khane16**	**Yes**
Administrator	**Borna Sadeghi**	**sadegb1**	**Yes**
Coordinator	**Amir Rayyan Khan**	**khana344**	**Yes**
Subject Matter Expert	**Zhenyu Zhao**	**zhaoz154**	**Yes**
Guest			

AGENDA ITEMS

1. Introductions
2. Work on Milestones

MEETING MINUTES

1. . Introductions
   a. Everyone introduced themselves and had some icebreakers
2. . Work on Milestones
   a. Roles assigned
   b. Worked on Who/Why ladders and objectives and constraints
   c. Created an initial problem statement and refined problem statement.

Milestone 2 Meeting Minutes

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Ehsaan Khan**	**khan16**	**Yes**
Administrator	**Borna Sadeghi**	**sadegb1**	**Yes**
Coordinator	**Amir Rayyan Khan**	**khana344**	**Yes**
Subject Matter Expert	**Zhenyu Zhao**	**zhaoz154**	**Yes**
Guest			

Agenda Items

1. . Attendance
2. . Pre-Design Studio
3. . Design Studio
4. . Questions

Meeting Minutes

1. . Attendance
    a. Took attendance of each member.
2. . Pre-Design Studio
    a. Finished up the pre-design studio
3. .Design Studio
    a. Worked on the design studio and finished it
4. .Questions
    a. No Questions were asked.

Milestone 3 Meeting Minutes

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Ehsaan Khan**	**khane16**	**Yes**
Administrator	**Borna Sadeghi**	**sadegb1**	**Yes**
Coordinator	**Amir Rayyan Khan**	**khana344**	**Yes**
Subject Matter Expert	**Zhenyu Zhao**	**zhaoz154**	**Yes**
Guest			

Agenda Items

1. . Attendance
2. . Progress - Modelling
3. . Progress - Computing
4. . Questions

Meeting Minutes

1. . Attendance
    a. Everyone here
    b. Small talk
2. . Progress - Modelling
    a. Created hand drawings of the prototype
    b. Started to model the prototype in Autodesk Inventor
3. . Progress - Computing
    a. Worked on an algorithm for sorting containers
    b. Created flowcharts and pseudocode for other functions
4. . Questions
    a. Are there different types of cans in the hopper at the same time -> No
    b. Will we need to use the scale that appears in the environment -> No
    c. Can we change the configuration of the sensors/chute -> No, use the position that Quanser initializes it to
    d. Do we need to follow the yellow line all the way around -> No

Post-Meeting Action Items

1. *Start working on the program*
2. *Start working on designing*

Milestone 4 Meeting Minutes

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Ehsaan Khan**	**khane16**	**Yes**
Administrator	**Borna Sadeghi**	**sadegb1**	**Yes**
Coordinator	**Amir Rayyan Khan**	**khana344**	**Yes**
Subject Matter Expert	**Zhenyu Zhao**	**zhaoz154**	**Yes**
Guest			

AGENDA ITEMS

1. . Design Presentation
2. . Review Designs
3. . Fill out Milestone 4
4. . Work on Feedback given for each sub-team

MEETING MINUTES

1. . **Design Presentation**
   a. **Computation**: showed the QArm picking up and dropping the container off
   b. Implement go home function
   c. pickup and drop off more than 1 container at a time
   d. **Modelling**: showed the actuator and hopper
   e. Asked him about the attachment from rung to the hopper
   f. Modelling design was good
2. . **Review Designs**
   a. Took mentor feedback into consideration to decide on how to move forward for each sub team.
3. . **Fill out Milestone 4**
   a. Each sub team filled out the Milestone 4 based on the feedback given and reviewing the designs.
4. . **Work on Feedback given for each sub-team**
   a. Each sub team went to work to improve their designs/code

Milestone 5 Meeting Minutes

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Ehsaan Khan**	**khane16**	**Yes**
Administrator	**Borna Sadeghi**	**sadegb1**	**Yes**
Coordinator	**Amir Rayyan Khan**	**khana344**	**Yes**
Subject Matter Expert	**Zhenyu Zhao**	**zhaoz154**	**Yes**
Guest			

Agenda Items

1. . **Sub team updates**
2. . **Work on sub-projects**

Meeting Minutes

1. **Attendance**
    a. Everyone here
2. **Subteam updates**
    a. **Modelling Sub team:** Playing around with the constrains, mostly done. Also have to work on the rotations a little bit.
    b. **Computing Sub team:** made lots of progress in the last 10 minutes of the previous design studio. Need to work on containers dropping into the hopper because the physics are glitchy.
3. . **Work on Sub-projects**
    a. Split off into different meetings to work on sub projects.

Design Studio Worksheets(group)

Milestone 0

PROJECT THREE: MILESTONE 0 – COVER PAGE

Team Number: Tues-24

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Ehsaan Khan	khane16
Borna Sadeghi	sadegb1
Zhenyu Zhao	zhaoz154
Amir Rayyan Khan	khana344

Insert your Team Portrait in the dialog box below

MILESTONE 0 – TEAM CHARTER

Team Number: Tues-24

Incoming Personnel Administrative Portfolio:

Prior to identifying Leads, identify each team members incoming experience with various **Project Leads**

	Team Member Name:	Project Leads
1.	Borna Sadeghi	☐**M** ☐A ☐C ☐**S**
2.	Ehsaan Khan	☐M ☐A ☐**C** ☐**S**
3.	Zhenyu Zhao	☐M ☐**A** ☐**C** ☐S
4.	Amir Rayyan Khan	☐M ☐**A** ☐C ☐**S**
		☐M ☐A ☐C ☐S

To 'check' each box in the Project Leads column, you must have this document open in the Microsoft Word Desktop App (not the browser and not MS Teams)

Project Leads:

Identify team member details (Name and MACID) in the space below.

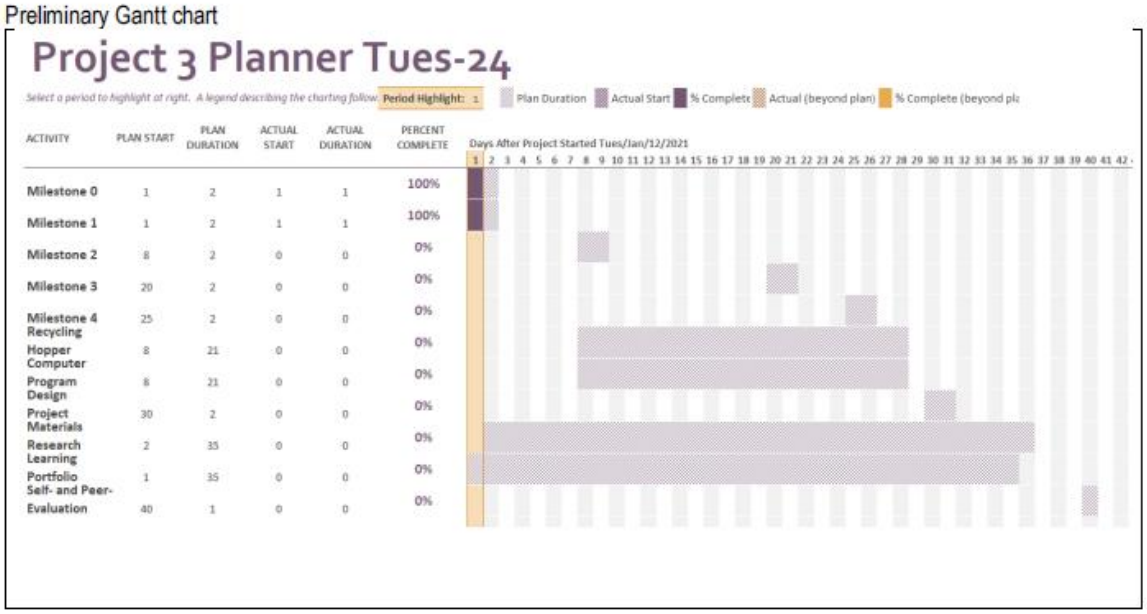
Role:	Team Member Name:	MacID
Manager	Ehsaan Khan	khane16
Administrator	Borna Sadeghi	sadegb1
Coordinator	Amir Rayyan Khan	khana344
Subject Matter Expert	Zhenyu Zhao	zhaoz154

MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team Number: Tues-24

Full Name of Team Manager:	MacID:
Ehsaan Khan	khane16

Preliminary Gantt chart



Milestone 1

PROJECT THREE: MILESTONE 1 – COVER PAGE

Team Number: Tues-24

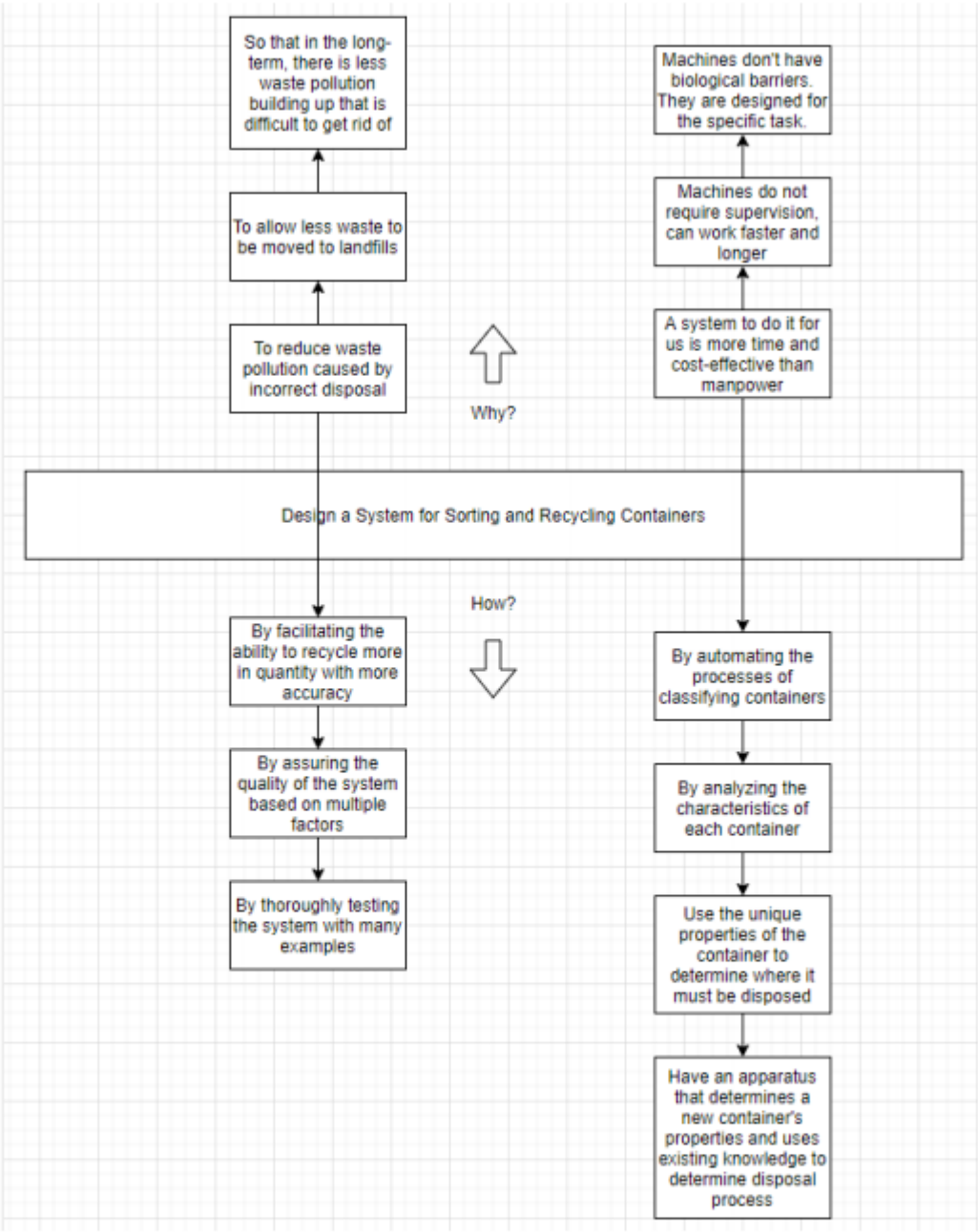
Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Ehsaan Khan	khane16
Borna Sadeghi	sadegb1
Amir Rayyan Khan	khana344
Zhenyu Zhao	zhaoz154

MILESTONE 1 (STAGE 1) – WHY/HOW LADDERING

Team Number: Tues-24

1. Document both your conversation and a refined visual on a separate sheet of paper
2. Take a photo of both your rough work and refined visual
3. Insert each photo as a Picture (Insert > Picture > This Device)
4. **Do not include more than one Picture per page**


So that in the long-term, there is less waste pollution building up that is difficult to get rid of
To allow less waste to be moved to landfills
To reduce waste pollution caused by incorrect disposal
Why?
Machines don't have biological barriers. They are designed for the specific task.
Machines do not require supervision, can work faster and longer
A system to do it for us is more time and cost-effective than manpower
Design a System for Sorting and Recycling Containers
How?
By facilitating the ability to recycle more in quantity with more accuracy
By assuring the quality of the system based on multiple factors
By thoroughly testing the system with many examples
By automating the processes of classifying containers
By analyzing the characteristics of each container
Use the unique properties of the container to determine where it must be disposed
Have an apparatus that determines a new container's properties and uses existing knowledge to determine disposal process

MILESTONE 1 (STAGE 2) – LIST OF OBJECTIVES AND CONSTRAINTS

Team Number: Tues-24

As a team, create a list of objectives and constraints in the table below. The exact number you should have depends on what information you have gathered from the Project Pack as well your previously completed needs hierarchy.

Objectives	- Device should be able to identify all types of container materials - Device must be able to classify containers as recyclable or non-recyclable - Arm should be able to grasp all types of containers - Q-bot should be able to collect containers from arm - Q-bot should deposit containers into the correct bin - Hopper must be able to mount to a base plate on top of the Q-bot - Arm must be able to place any container into the hopper - The design of the hopper should allow the actuator to move it
Constraints	- Size of the hopper is small enough to fit on the base plate - Size of the hopper is large enough to fit all types of containers - The Q-bot hopper should be able to carry more than 90 grams - Hopper must be cost-effective to develop

MILESTONE 1 (STAGE 3) – REFINED PROBLEM STATEMENT

Team Number: Tues-24

Initial Problem Statement

1. Write the initial problem statement in the space below. This will have been defined in a previous lecture, prior to your scheduled Design Studio.

Design a system for sorting and recycling containers.

Who needs *what* because *why*?

Refined Problem Statement

2. Write the refined problem statement below. Kindly refer to the Refined Problem Statement rubric provided on Avenue (see P3 Rubrics). This will guide your group in creating a valid statement.

Improper recycling processes could lead to a detrimental effect on the environment as waste becomes misplaced, so the recycling process of materials must be made more accurate, fast, and efficient.

Milestone 2

PROJECT THREE: MILESTONE 2 – COVER PAGE

Team Number: Tues-24

Please list full names and MacID's of all *present* Team Members.

Full Name:	MacID:
Ehsaan Khan	khane16
Zhenyu Zhao	zhaoz154
Borna Sadeghi	sadegb1
Amir Rayyan Khan	khana344

MILESTONE 2 (STAGE 1) – SENSOR RESEARCH (COMPUTATION SUB-TEAM)

Team Number: Tues-24

You should have already completed this task individually *prior* to Design Studio 14.

1. Each team member is expected to research 3 types of sensors for characterizing bins
   → Refer to Table 3 of the Computation Sub-Team Objectives document
2. For each sensor:
   → Briefly describe how the sensor works
   → Indicate the attribute you would measure to characterize each bin (refer to Table 4 of the Computation Sub-Team Objectives document)

We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their sensor research with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Tues-24

Name: Borna	MacID: sadegb1

Sensor Type	Description	Attributes
Hall Sensor	• Measures the magnitude of a magnetic field • Converts magnetic or magnetically encoded information into electrical signals for processing by electronic circuits (think of how a DC motor works) • Allows for the sensing of position, distance and speed of magnetic materials,	• Magnetic field • Position and movement (of magnetic parts)
Light-dependent resistor	• Also known as a photoresistor • Is passive (doesn't consume energy to work) • In brighter light, the resistance is lower	• Light level
Retro-reflective Photoelectric sensorsor	• Senses reflector or reflective materials at a long range • Consists of an emitter and a sensor • Emits directed light (e.g. laser) and detects the reflection back from the object	• Reflectivity • Transparency

Team Number: Tues-24

Name: Amir Rayyan Khan	MacID: khana344

Sensor Type	Description	Attribute(s)
Ultrasonic Sensor	• Consists of an emitter and detector • Detects distance to a target object by detecting reflections of emitted ultrasonic sound waves	• Proximity/Distance through air (doesn't work in a vacuum
Color Sensor	• Consists of an emitter and detector • Are very similar to cameras • Red, blue and green light are casted by the emitters to test for the colour of an object	• Detecting colour (even in the dark)
Active infrared (IR) sensor	• Both emit and detect infrared radiation (unlike passive IR sensors which only detect light from other sources (e.g. on a TV remote))	• Detecting heat and obstacles

MILESTONE 2 (STAGE 2) – CONCEPT SKETCHES (MODELLING SUB-TEAM)

Team Number: Tues-24

You should have already completed this task individually *prior* to Design Studio 14.

1. Copy-and-paste each sub-team member's refined sketch on the following pages (1 sketch per page)
   → Be sure to indicate each team member's Name and MacID

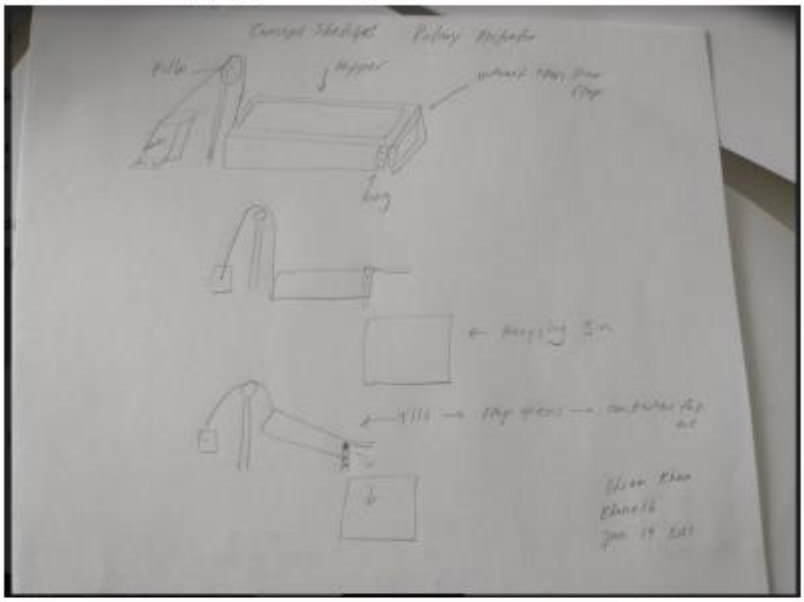
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

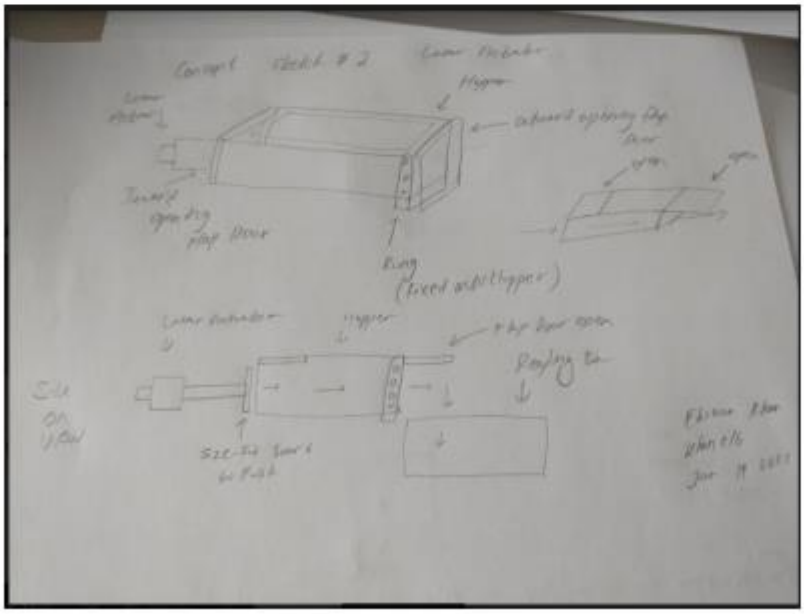
- Each team member needs to submit their concept sketches with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 4*** of the milestone

Team Number: Tues-24

Name: Ehsaan Khan	MacID: khane16

Insert screenshot(s) of your concept sketches below

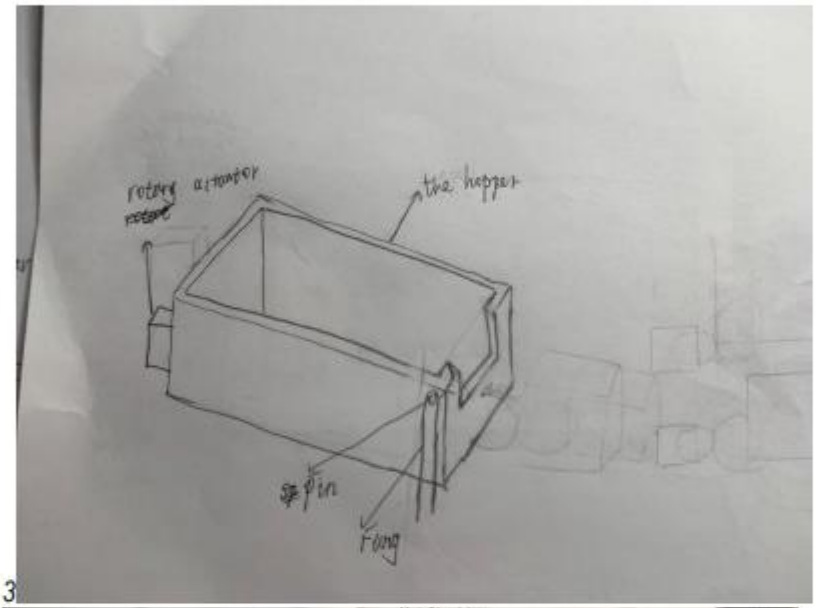




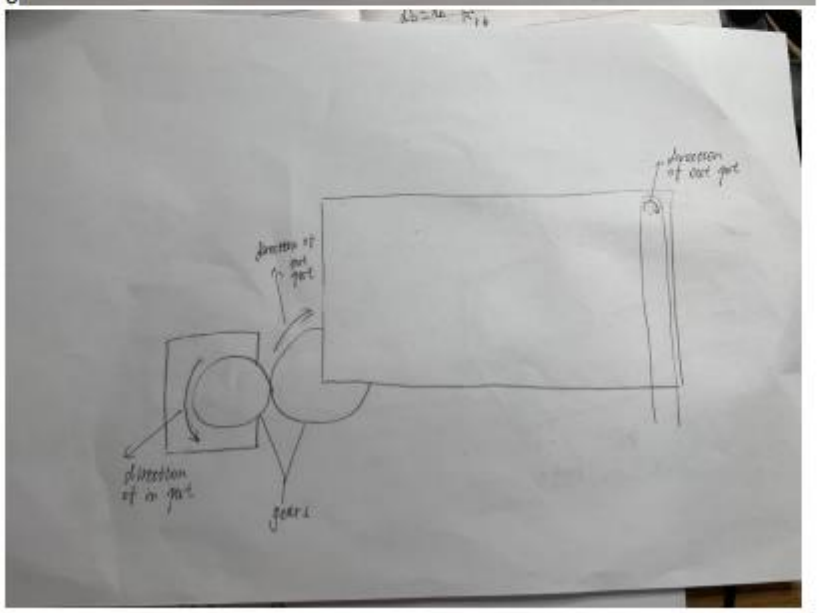
Team Number: Tues-24

Name: Zhenyu Zhao	MacID: zhaoz154

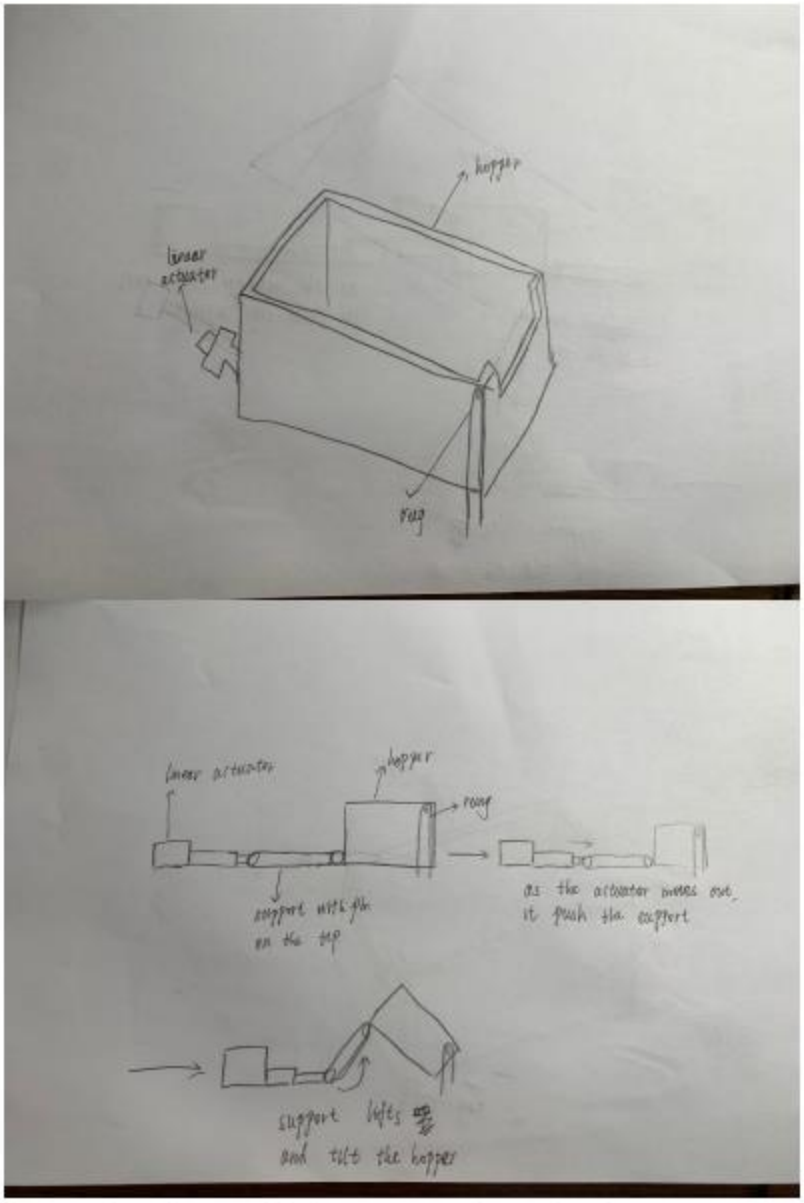
Insert screenshot(s) of your concept sketches below



3



4



*If you are in a sub-team of 3, please copy and paste the above on a new page

MILESTONE 2 (STAGE 3) – SENSOR CHARACTERIZATION (COMPUTATION SUB-TEAM)

Team Number: Tues-24

1. As a team, consolidate the results of your individual sensor research
   → Discuss your findings and appropriateness of each sensor for your application
   → Keep discussion brief, using point form

Sensor Type	Findings and Appropriateness for Application
Hall sensor	• Measures the magnitude of a magnetic field • Used for the sensing of position, distance and speed of magnetic materials. E.g. Found in wheel speed sensors • For application (classifying bins by an attribute), this might not be ideal because there is only the option to make a bin metallic, but even with all bins metallic and made of magnetic metal, it would be very difficult
Light-dependent resistor (light level sensor)	• A passive light-sensitive resistor that has a lower resistance in brighter light • Can be used to detect light level • Not ideal for bin classification because the light level must be kept constant, and must find a way to reflect a light source off of bins of varying reflectiveness
Retro-reflective photoelectric sensor	• Senses reflectivity of materials at a long range using an emitter and receiver of directed light (e.g. laser) • Potentially could vary the reflectivity, although this may require that the bins stay clean and reflective on the surface
Ultrasonic sensor	• Senses proximity/distance of objects through the air, by emitting and receiving ultrasonic sound • The bins can be offset by a certain distance from the yellow line for identification • Probably most cost-effective way to classify by distance, but this requires the bins to be farther, which means more travel, which means less efficiency (more time spent, more energy used)
Color sensor	• Similar to cameras, emit and detect visible red, blue and green light to test • A very effective way to classify bins, assuming the colour stays somewhat the same. Even for a washed out and worn down blue

	container, it's still easy to distinguish it from a red container. Also great longevity, reliability, production
Active infrared (IR) sensor	• Both emit and detect infrared radiation (unlike passive IR sensors which only detect light from other sources (e.g. on a TV remote)) • Can be used to detect heat, obstacles, motion • Using IR to classify bins can be difficult, their main unique properties are the ability to detect heat. This part isn't a very useful feature in this case since there's no way to vary the heat, but they can also detect obstacles and distances like some of the other sensors, and unlike the ultrasonic sensor, it will work in a vacuum or moving air conditions

2. Identify one sensor to incorporate into your computer program

Colour sensor, because it is easy to make the bins distinguishable in this way, and since colour is less prone to being read incorrectly. Also, we know for sure that there is the option to change the colour of the bins in the Quanser environment.

3. Identify an attribute value for each bin

Bin ID	**Attribute Value (colour, RGB)**
Bin01: Metal Bin	Red
Bin02: Paper Bin	Green
Bin03: Plastic Bin	Blue
Bin04: Garbage Bin	White

MILESTONE 2 (STAGE 4) – DECISION MATRIX (MODELLING SUB-TEAM)

Team Number: Tues-24

1. As a team, establish a weighting factor for each criterion
   → Move row-by-row

- If *Criteria 1* is preferred over *Criteria 2*, assign a 1. Otherwise, assign 0
- If *Criteria 1* is preferred over *Criteria 3*, assign a 1. Otherwise, assign 0

→ Add additional rows/columns as needed

	Weight	*Size*	*Cost*	Stability	Compatibility(w/ actuator)		**Score**
Weight	1	1	1	0	0		3
Size	0	1	1	0	0		2
Cost	0	0	1	0	0		1
Stability	1	1	1	1	0		4
Compatibility(w/ actuator)	1	1	1	1	1		5

2. As a team, evaluate your concepts against each criterion using your weighting

→ Add additional rows as needed

	Weight	*Concept 1*		*Concept 2*		*Concept 3*		*Concept 4*	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Weight	3	3	9	4	12	3	9	2	6
Size	2	2	4	2	4	4	8	3	6
Cost	1	3	3	4	3	3	3	4	4
Stability	4	4	16	4	16	2	8	4	16
Compatibility (w/ actuator)	5	4	20	3	15	3	15	4	20
TOTAL	15	16	**52**	17	**50**	15	**43**	17	**52**

3. Discuss conclusions based on evaluation, including what concept you've chosen

Concept 4, had the highest(tied) score in the decision matrix chart. We believe it taking everything into consideration, like the criterion, is the best concept, and we will go ahead with this one. We find this is both a simple, yet effective and importantly, practical design. It also scored highest in the two most important criterion of Stability and Compatibility(with the actuator). If fulfills the condition, of rotating about the rung. This design can also be repeated many times, as needed in a recycling facility. This design needs some work and we believe, it will result in a very good design. The design is drawn out and described in detail in the sketches above.

Milestone3

PROJECT THREE: MILESTONE 3 – COVER PAGE

Team Number: Tues-24

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Borna Sadeghi	sadegb1
Amir Rayyan Khan	khana344
Zhenyu Zhao	zhaoz154
Ehsaan Khan	khane16

MILESTONE 3 (STAGE 1A) – WORKFLOW PSEUDOCODE (COMPUTATION SUB-TEAM)

Team Number: Tues-24

You should have already completed this task individually *prior* to Design Studio 15.

1. Write out a pseudocode outlining the *high-level workflow* of your computer program on the following page
   → Only one team member is responsible for this task (not *both*)
   → Be sure to clearly indicate who each code belongs to

We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their pseudocode with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Tues-24

Name: Amir Rayyan Khan	MacID: khana344

*Write out a pseudocode outlining the **high-level workflow** of your computer program in the space below.*

```
>>>start
If position q-arm = home and if position q-bot = home:
    Determine container attributes(mass)
If container mass = X:
        Destination =  paper bin
Elif container mass = Y
        Destination = plastic bin
Elif container mass = Z
        Destination is garbage bin
q-arm moves next to the container
q-arm closes gripper
q-arm moves towards hopper
q-arm opens gripper
q-arm position = home
repeat till 3 containers on hopper or totalmass is >90 or ID is different in the sorting station compared to the hopper
q-bot moves forward
detectedcolour =sensor detects colour
if detectedcolour = paperbin colour
bin = paper bin
if detectedcolour = plasticbin colour
bin = plastic bin
if detectedcolour = metalbin colour
```

bin = metal bin
if detectedcolour = garbagebin colour
bin = garbage bin
if bin = destination bin
tilt hopper to empty container into the bin
hopper position back to zero
go back to home position
*repeat above^*

MILESTONE 3 (STAGE 1B) – WORKFLOW FLOWCHART / STORYBOARD (COMPUTATION SUB-TEAM)

Team Number: Tues-24

You should have already completed this task individually *prior* to Design Studio 15.

1. Only one team member is responsible for this task (not *both*)
2. Copy-and-paste your flowchart or storyboard on the following page
   → Be sure to include your Team Number, Name and MacID
3. Take a photo of your flowchart / storyboard
4. Insert your photo as a Picture (Insert > Picture > This Device)

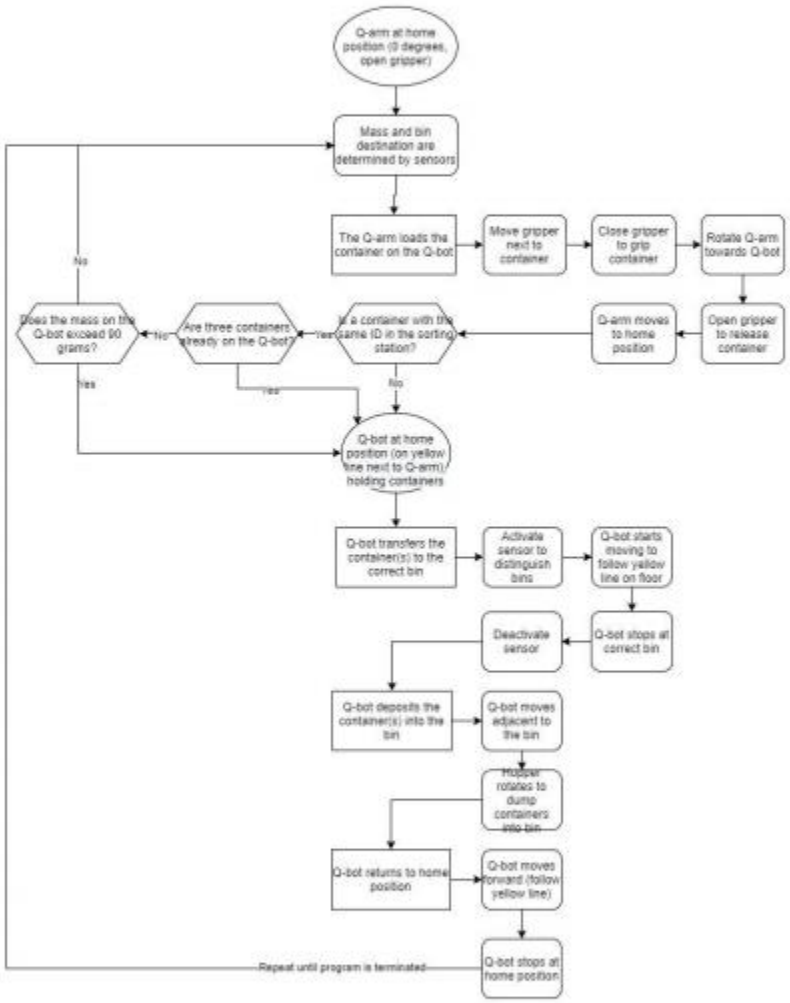
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their flowchart/storyboard screenshots with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Tues-24

Name: Borna Sadeghi	MacID: sadegb1

Insert screenshot(s) of your flowchart or storyboard.



MILESTONE 3 (STAGE 2) – DETAILED SKETCHES (MODELLING SUB-TEAM)

Team Number: Tues-24

You should have already completed this task individually *prior* to Design Studio 15.

1. Copy-and-paste each sub-team member's detailed sketch on the following pages (1 sketch per page)
   → Be sure to indicate each team member's Name and MacID

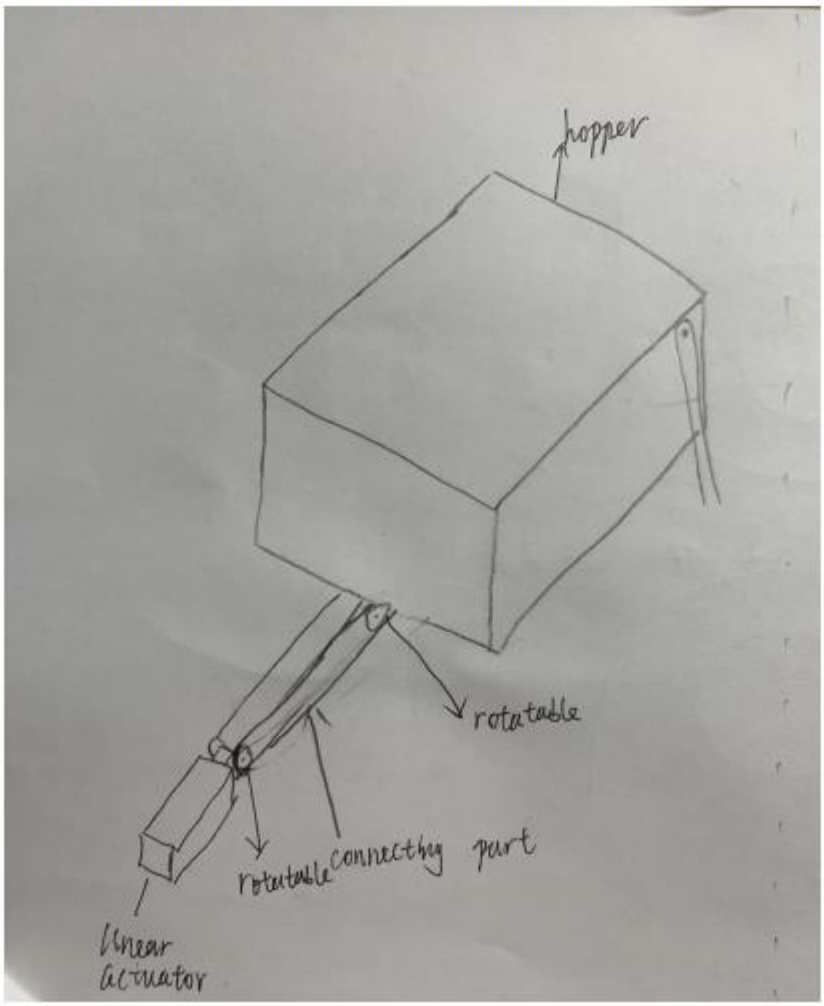
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

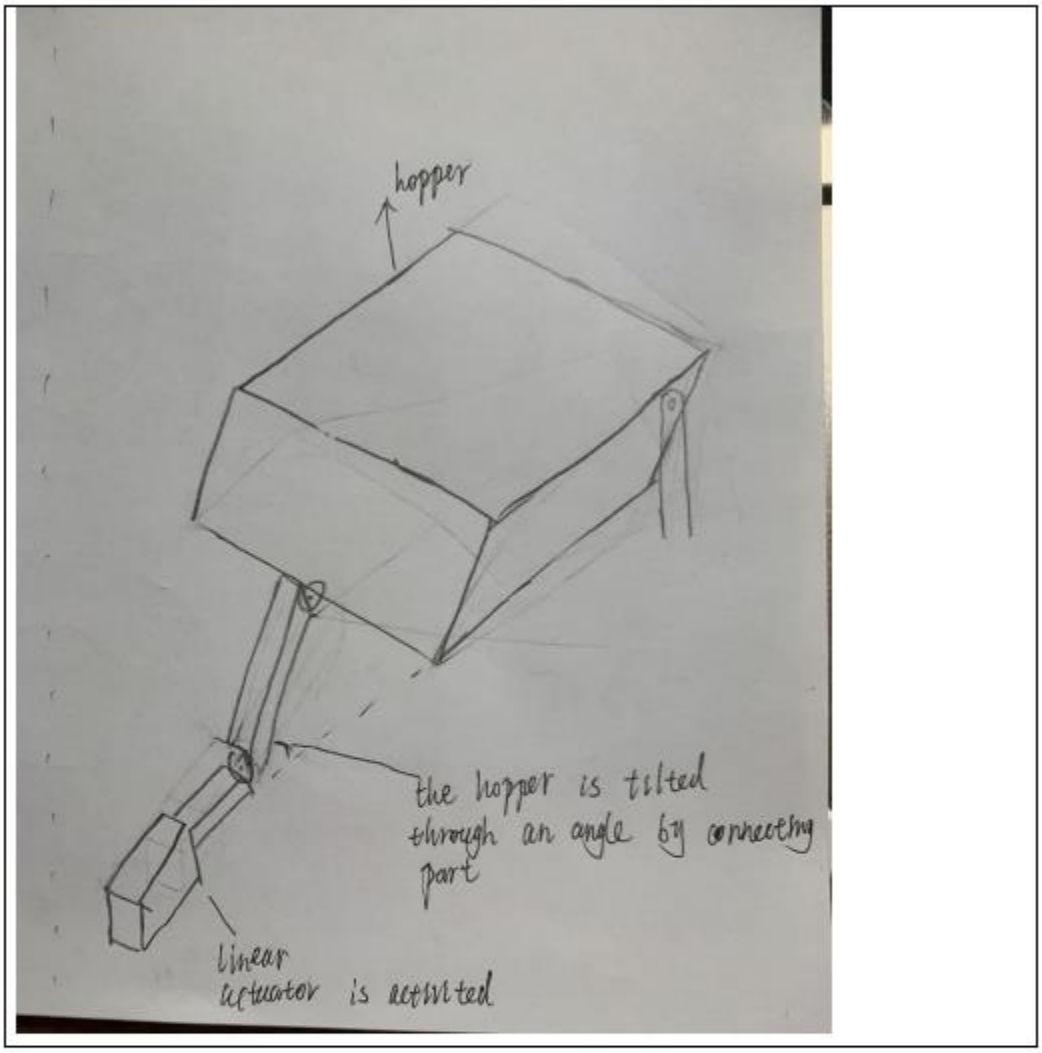
- Each team member needs to submit their detailed sketches with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 4*** of the milestone

Team Number: Tues-24

Name: Zhenyu Zhao	MacID: zhaoz154

Insert screenshot(s) of your detailed sketch below.

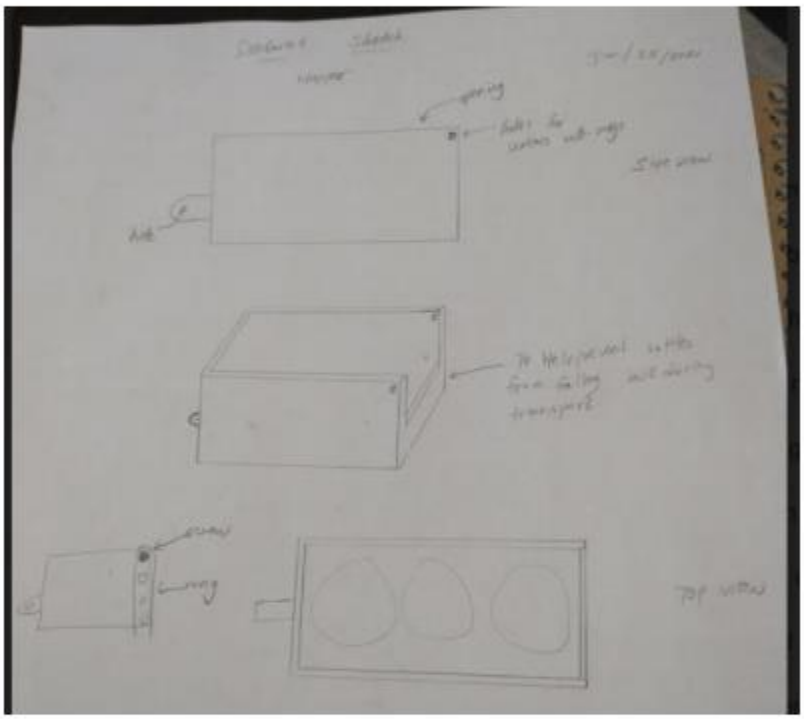



hopper
the hopper is tilted through an angle by connecting part
linear actuator is activated

Team Number: Tues-24

Name: Ehsaan Khan	MacID khane16

Insert screenshot(s) of your detailed sketch below.



*If you are in a sub-team of 3, please copy and paste the above on a new page.

MILESTONE 3 (STAGE 3) – PROGRAM TASK PLANNING (COMPUTATION SUB-TEAM)

Team Number: Tues-24

1. As a team, write out the pseudocode or create a flowchart for the indicated tasks in the space below.
   → If creating a flowchart, complete your flowchart on a separate sheet of paper, take a photo of your sketch and insert photo as a Picture (Insert > Picture > This Device)

Dispense Container

Container is dispensed, turntable rotates, sensor classifies container, rotate turntable so container is closest to Q-arm

Drop container from chute

Classify container with sensor (keep track of these types in a list)

If no item appears 3+ times, fill slots until either slots full or 3 of a kind

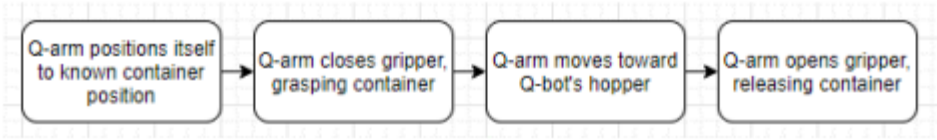
The most frequently occurring container is rotated to "index 0" (directly in front of the Q-arm)

If there is a tie, take the containers that minimize rotation distance in order to pick them all up

Afterwards, rotate the empty slots to "index 6" (where the chute is) and repeat

Load Container

Q-arm picks up container and moves it to Q-bot's hopper



Transfer Container

Q-bot to recycling station (identify bins in the process)

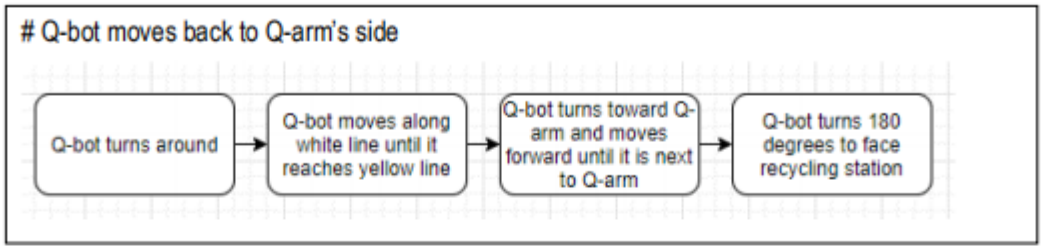
Deposit Container

Q-bot dumps the containers into the bin

Rotate hopper into the bin as much as possible to ensure all the containers are deposited

Rotate hopper back to normal position

Return Home



MILESTONE 3 (STAGE 4) – PRELIMINARY MODELLING (MODELLING SUB-TEAM)

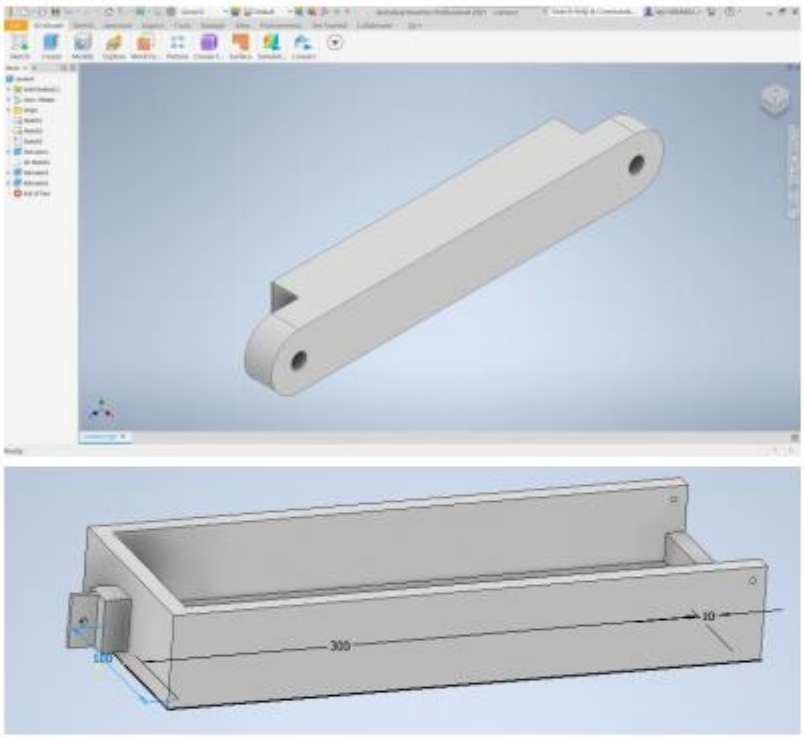
Team Number: Tues-24

1. As a team, create solid models of the various components of your device in Autodesk Inventor, based on the detailed sketches.
   → Take multiple screenshots of each solid model you create
   → Insert your photo(s) as a Picture (Insert > Picture > This Device)
   → **Do not include more than *two* solid modelling screenshots per page**

Team Number: Tues-24

Name: Ehsaan Khan, Zhenyu Zhao	MacID khane16, zhaoz154

Insert screenshot(s) of your model below.



*Limit screenshots to no more than 2 per page. For additional screenshots, please copy and paste the above on a new page

Mileston4

PROJECT THREE: MILESTONE 4 – COVER PAGE

Team Number: Tues-24

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Ehsaan Khan	khan16
Zhenyu Zhao	zhaoz154
Borna Sadeghi	sadegb1
Amir Rayyan Khan	khana344

MILESTONE 4 (STAGE 3) – DESIGN REVIEW FEEDBACK (MODELLING SUB-TEAM)

Team Number: Tues-24

Use the space below to document mentor feedback for your design.

1. Constrain the actuator on angle so that it would not over-extend the hopper
2. Re-sketch the hopper so that it is same size with the actuator

Modelling Feedback and Questions:

-Rung connection? Screws are good enough

-play around with hopper connection and constraint to the right angle

-get the sketch to the same measurements

-get the assembly together and play around for movement

Use the space below to propose design refinements based on the feedback.

-getting the sketches to be the same dimension

-make sure the connecting pin doesn't move completely freely at the hopper end

-trial and error

MILESTONE 4 (STAGE 3) – DESIGN REVIEW FEEDBACK (COMPUTATION SUB-TEAM)

Team Number: Tues-24

Use the space below to document mentor feedback for your design.

- Make more time efficient by loading multiple containers at once
- Ensure the Q-bot can come home
- Tweak the container loading and dispensing, as currently it is disobeying physics

Use the space below to propose design refinements based on the feedback.

- In final program, when container loaded, wait for more containers as long as hopper mass is less than 90 grams
- Implement a go home function where the QBot goes back to under the QArm after dumping the containers.
- Figure out what lost lines means in the follow_line function (might not be necessary)

Design Studio Worksheets(individual)

Milestone2

MILESTONE 2 (STAGE 1) – SENSOR RESEARCH (COMPUTATION SUB-TEAM)

Team Number: Tues-24

Complete this worksheet individually *before* coming to Design Studio 14.

1. Each team member is expected to research 3 types of sensors for characterizing bins
   → Refer to Table 3 of the Computation Sub-Team Objectives document
2. For each sensor:
   → Briefly describe how the sensor works
   → Indicate the attribute you would measure to characterize each bin (refer to Table 4 of the Computation Sub-Team Objectives document)
1. Complete your sensor research on the following page
   → Be sure to clearly write your Team Number, Name and MacID

At the beginning of Design Studio, we will be asking that you copy-and-paste the tables into the **Milestone Two Team Worksheets.** It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their sensor research with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Tues-24

Name: Amir Rayyan Khan	MacID: khana344

Sensor Type	Description	Attribute(s)
Ultrasonic Sensor	• Consists of an emitter and detector • Detects distance to a target object by detecting reflections of emitted ultrasonic sound waves	Proximity/Distance through air (doesn't work in a vacuum
Color Sensor	• Consists of an emitter and detector • Are very similar to cameras • Red, blue and green light are casted by the emitters to test for the colour of an object	Detecting colour (even in the dark)
Active infrared (IR) sensor	• Both emit and detect infrared radiation (unlike passive IR sensors which only detect light from other sources (e.g. on a TV remote))	Detecting heat and obstacles

MILESTONE 2 (STAGE 2) – CONCEPT SKETCHES (MODELLING SUB-TEAM)

Team Number: Tues-24

Complete this worksheet individually *before* coming to Design Studio 14.

1. Complete your sketch on a separate sheet of paper
   → Be sure to clearly write your Team Number, Name and MacID
2. Take a photo of your sketch
3. Insert your photo as a Picture (Insert > Picture > This Device)

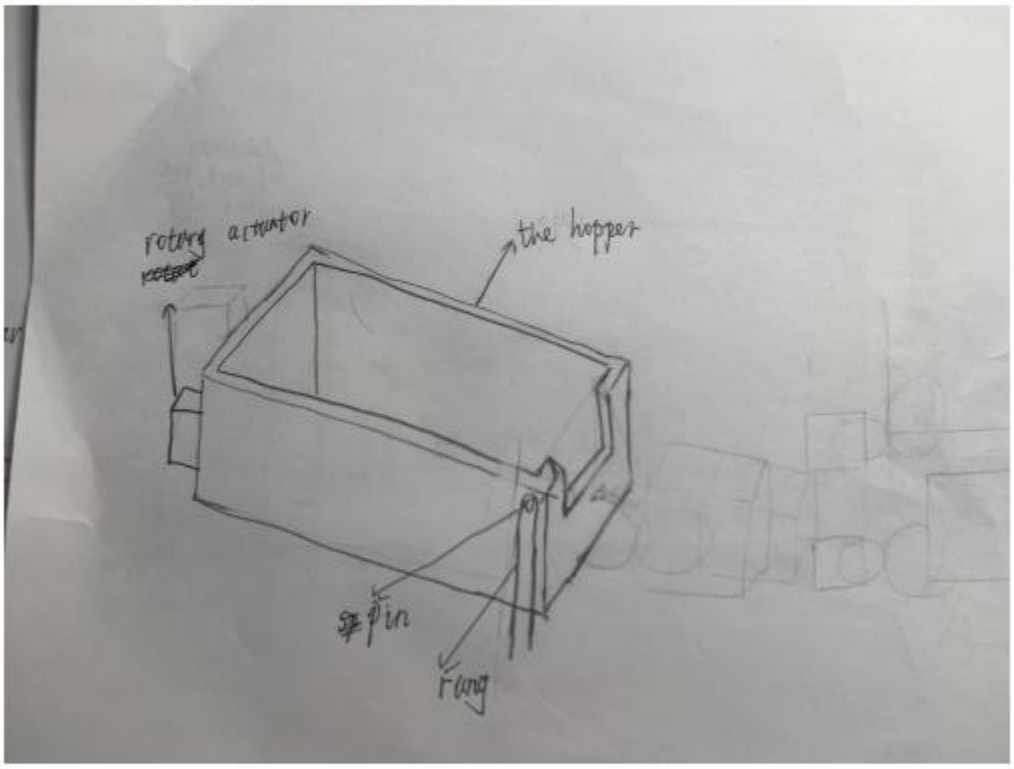
At the beginning of Design Studio, we will be asking that you copy-and-paste the same photos into **Milestone Two Team Worksheets.** It does seem redundant, but there are valid reasons for this:

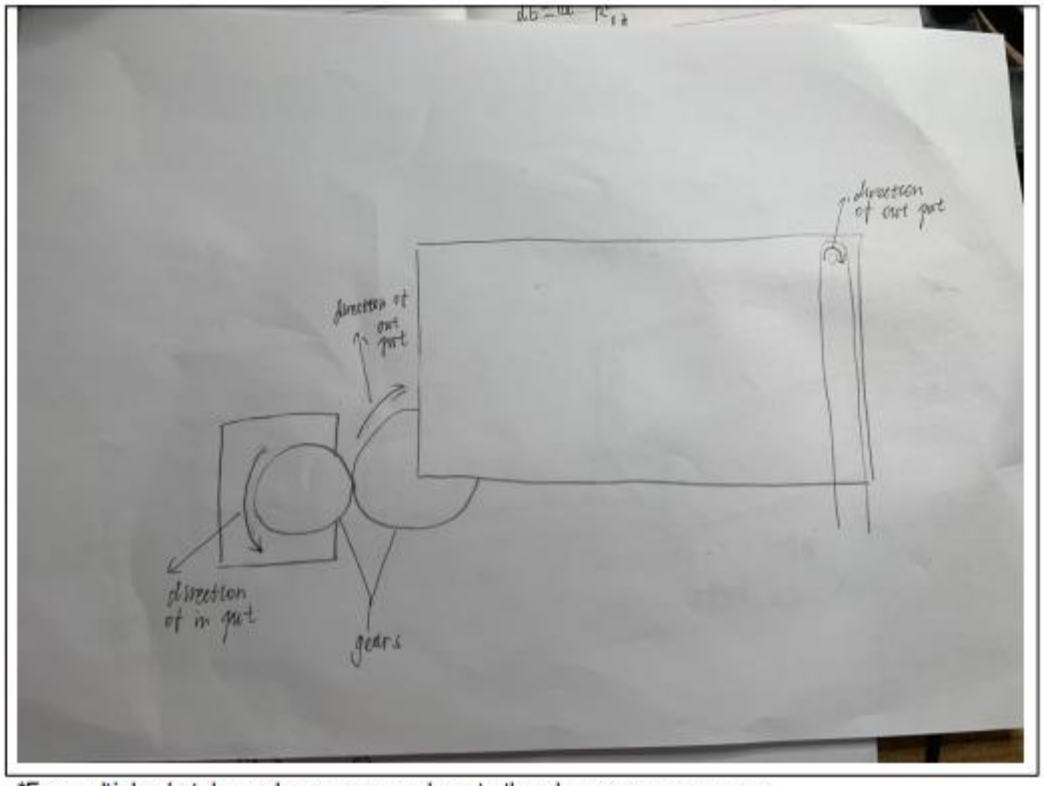
- Each team member needs to submit their concept sketches with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 4*** of the milestone

Team Number: TUES-24

Name: Zhenyu Zhao	MacID: zhaoz154

Insert screenshot(s) of your refined sketch below



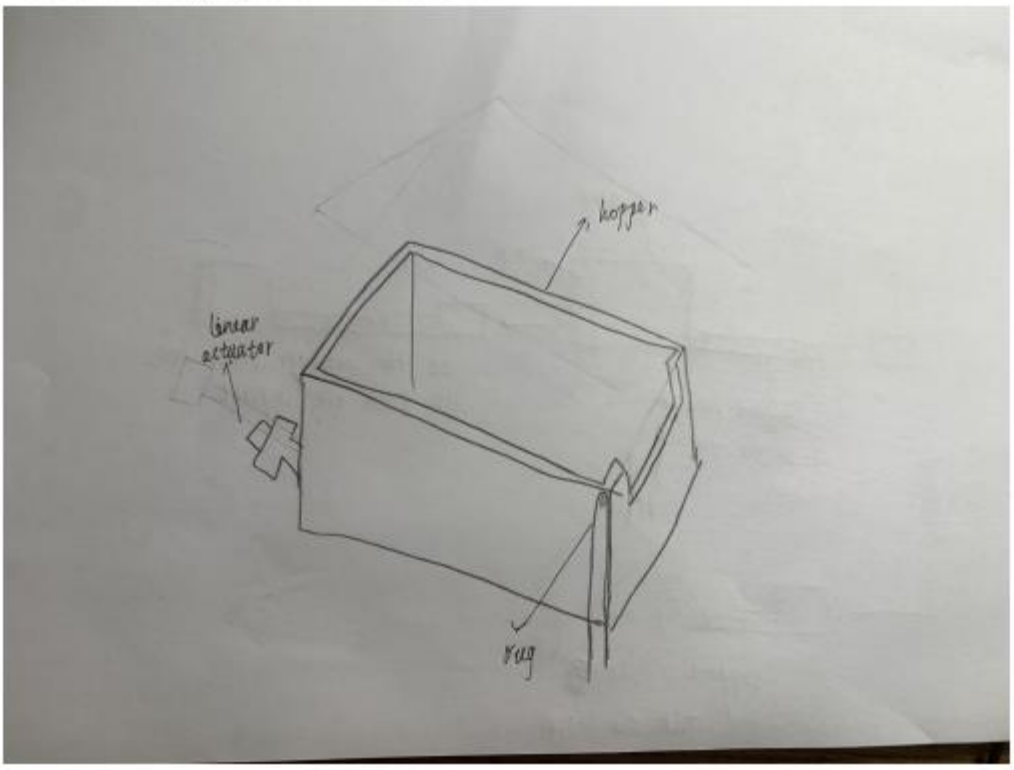


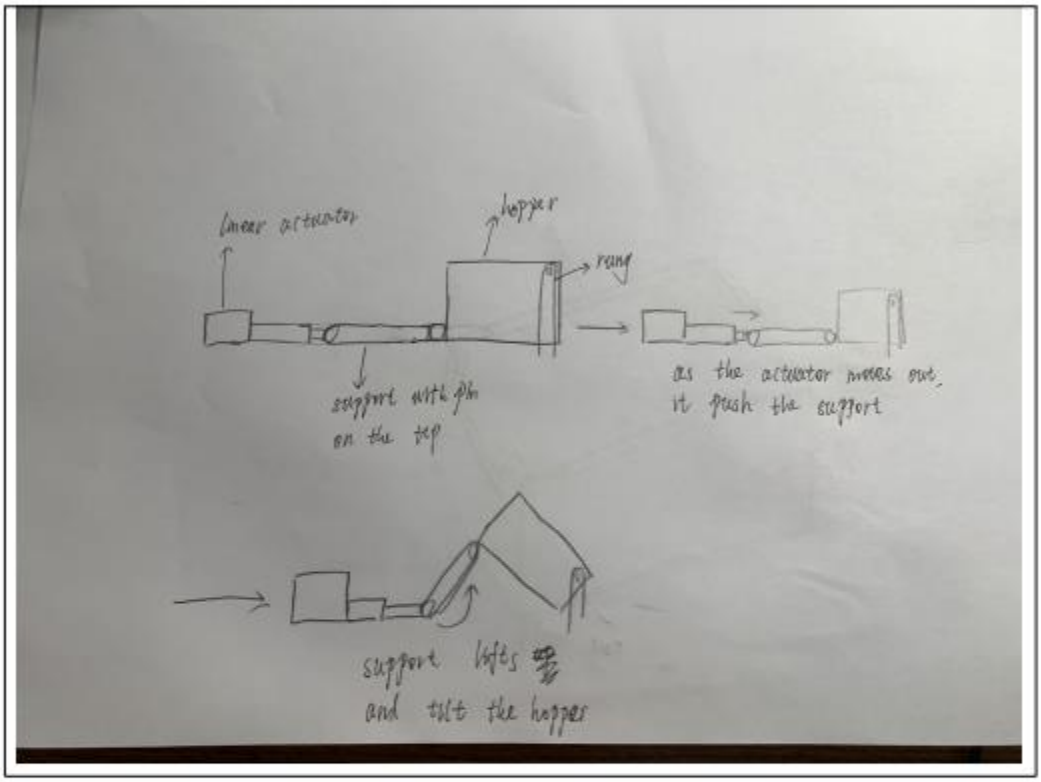
*For multiple sketches, please copy and paste the above on a new page

Team Number: TUES-24

Name: Zhenyu Zhao	MacID: zhaoz154

Insert screenshot(s) of your refined sketch below




Linear actuator
hopper
rung
support with pin on the top
as the actuator moves out, it push the support
support lifts up and tilt the hopper

MILESTONE 2 (STAGE 1) – SENSOR RESEARCH (COMPUTATION SUB-TEAM)

Team Number: Tues-24

Complete this worksheet individually *before* coming to Design Studio 14.

1. Each team member is expected to research 3 types of sensors for characterizing bins
   → Refer to Table 3 of the Computation Sub-Team Objectives document
2. For each sensor:
   → Briefly describe how the sensor works
   → Indicate the attribute you would measure to characterize each bin (refer to Table 4 of the Computation Sub-Team Objectives document)
1. Complete your sensor research on the following page
   → Be sure to clearly write your Team Number, Name and MacID

At the beginning of Design Studio, we will be asking that you copy-and-paste the tables into the **Milestone Two Team Worksheets.** It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their sensor research with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Tues-24

Name: Borna Sadeghi	MacID: sadegb1

Sensor Type	Description	Attribute(s)
Hall Sensor	• Measures the magnitude of a magnetic field • Converts magnetic or magnetically encoded information into electrical signals for processing by electronic circuits (think of how a DC motor works) • Allows for the sensing of position, distance and speed of magnetic materials • For application (classifying bins by an attribute), this might not be ideal because there is only the option to make a bin metallic, but even with all bins metallic and made of magnetic metal, it would be very difficult	• Magnetic field • Position and movement (of magnetic parts)
Light-dependent resistor	• Also known as a photoresistor • Is passive (doesn't consume energy to work) • In brighter light, the resistance is lower • Not ideal for bin classification because the light level must be kept constant, and must find a way to reflect a light source off of bins of varying reflectiveness	• Light level
Retro-reflective Photoelectric sensor	• Senses reflector or reflective materials at a long range • Consists of an emitter and a sensor • Emits directed light (e.g. laser) and detects the reflection back from the object • Potentially could vary the reflectivity, although this may require that the bins stay clean and reflective on the surface	• Reflectivity • Transparency

Milestone3

MILESTONE 3 (STAGE 1A) – WORKFLOW PSEUDOCODE (COMPUTATION SUB-TEAM)

Team Number: Tues-24

Complete this worksheet individually *before* coming to Design Studio 15.

1. Write out a pseudocode outlining the *high-level workflow* of your computer program on the following page
   → Only one team member is responsible for this task (not *both*)
   → Be sure to clearly indicate who each code belongs to

At the beginning of Design Studio, we will be asking that you copy-and-paste your work into **Milestone Three Team Worksheets.** It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their pseudocode with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into the **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Tues-24

Name:Amir Rayyan Khan	MacID: khana344

*Write out a pseudocode outlining the **high-level workflow** of your computer program in the space below.*

```
>>>start
If position q-arm = home and if position q-bot = home:
        Determine container attributes(mass)
        If container mass = X:
                Destination =  paper bin
        Elif container mass = Y
                Destination = plastic bin
        Elif container mass = Z
                Destination is garbage bin
        q-arm moves next to the container
        q-arm closes gripper
        q-arm moves towards hopper
        q-arm opens gripper
        q-arm position = home
        repeat till 3 containers on hopper or totalmass is >90 or...??
q-bot moves forward
        detectedcolour =sensor detects colour
        if detectedcolour = red
                bin = paper bin
        if detectedcolour = blue
                bin = plastic bin
        if detectedcolour = white
                bin = metal bin
        if detectedcolour = black
```

```
                bin = garbage bin
        if bin = destination bin
                tilt hopper to empty container into the bin
                hopper position back to zero
                go back to home position
repeat above^
```

MILESTONE 3 (STAGE 1A) – WORKFLOW PSEUDOCODE (COMPUTATION SUB-TEAM)

Team Number: Tues-24

Complete this worksheet individually *before* coming to Design Studio 15.

1. Write out a pseudocode outlining the *high-level workflow* of your computer program on the following page
   → Only one team member is responsible for this task (not *both*)
   → Be sure to clearly indicate who each code belongs to

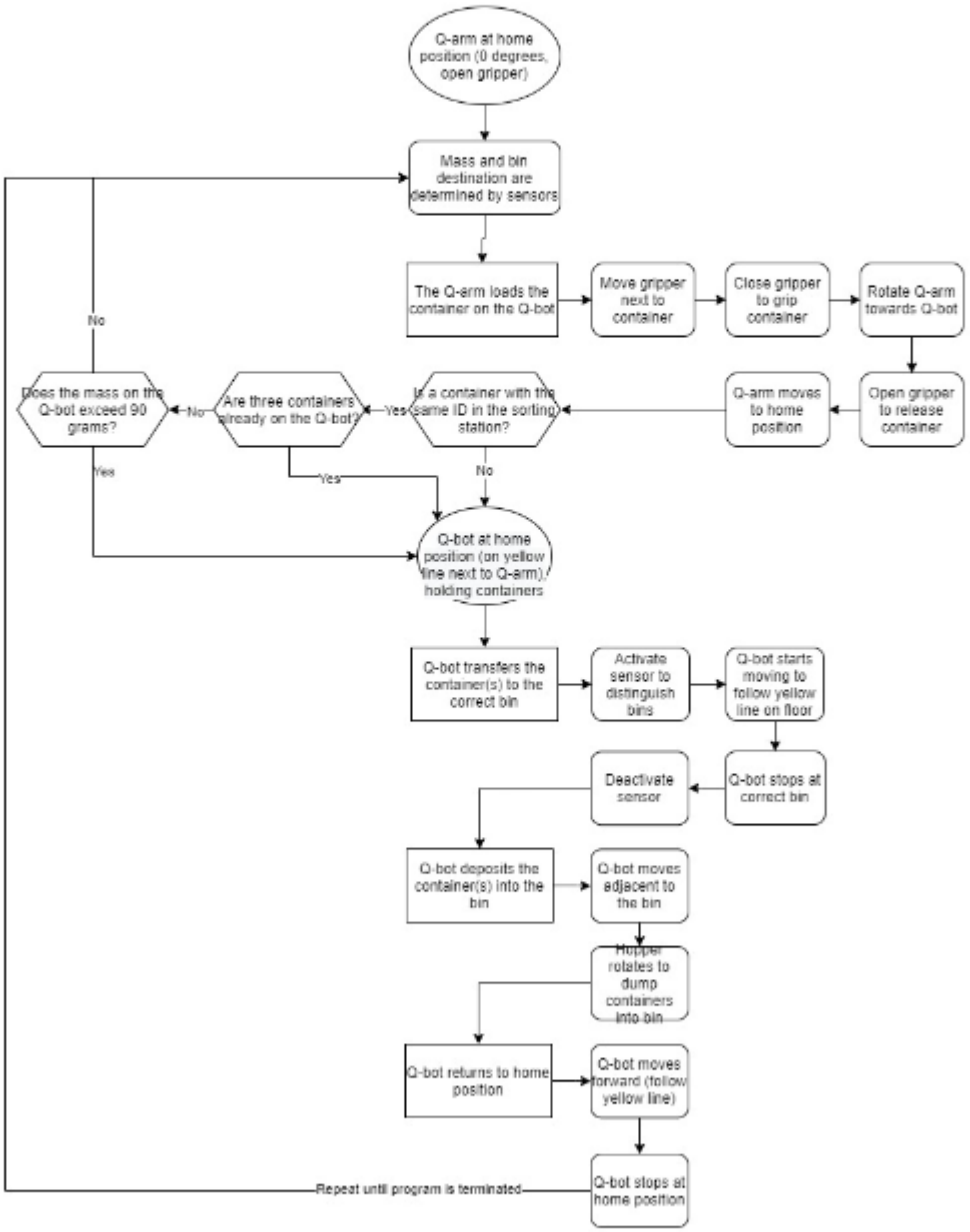
At the beginning of Design Studio, we will be asking that you copy-and-paste your work into **Milestone Three Team Worksheets.** It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their pseudocode with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into the **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Tues-24

Name: Borna Sadeghi	MacID: sadegb1

Insert screenshot(s) of your flowchart or storyboard.



MILESTONE 3 (STAGE 2) – DETAILED SKETCHES (MODELLING SUB-TEAM)

Team Number: Tues-24

Complete this worksheet individually *before* coming to Design Studio 15.

1. Complete your sketch on a separate sheet of paper
   → Be sure to indicate each team member's Name and MacID
2. Take a photo of your sketch
3. Insert your photo as a Picture (Insert > Picture > This Device)

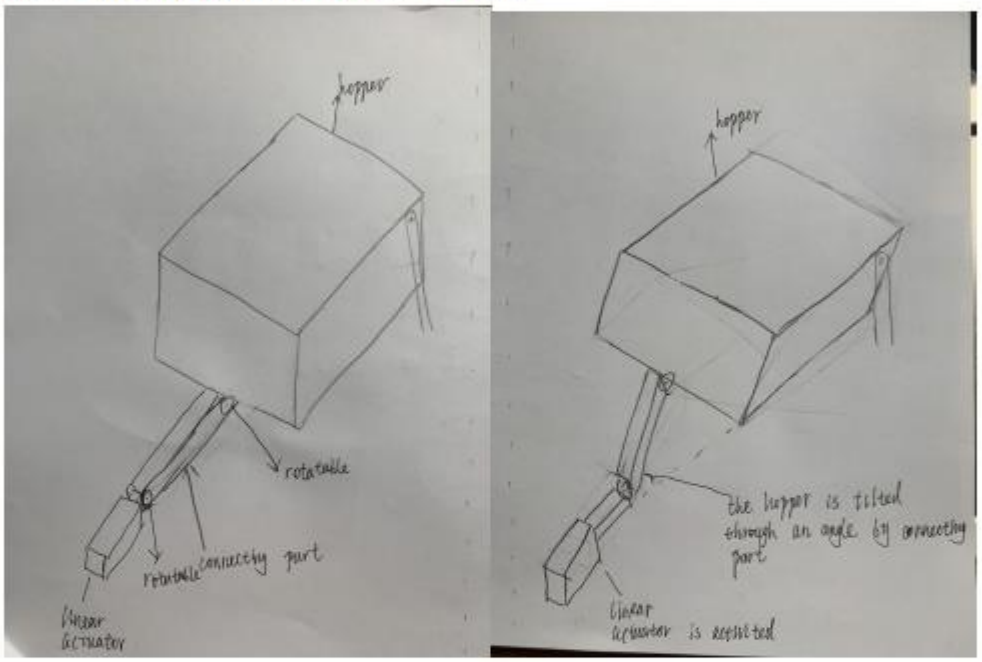
At the beginning of Design Studio, we will be asking that you copy-and-paste the same photos into **Milestone Three Team Worksheets.** It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their detailed sketches with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 4*** of the milestone

Team Number: Tues-24

Name:Zhenyu Zhao	MacIDzhaoz154

Insert screenshot(s) of your detailed sketch below.



*For multiple sketches, please copy and paste the above on a new page.

Sources

[1]"Ultrasonic transducer", *En.wikipedia.org*. [Online]. Available: https://en.wikipedia.org/wiki/Ultrasonic_transducer.

[2]"What is an Ultrasonic Sensor?", *FierceElectronics*, 2019. [Online]. Available: https://www.fierceelectronics.com/sensors/what-ultrasonic-sensor. [Accessed: 03- Mar- 2021].

[3]"Ultrasonic Sensors: Answers to Frequently Asked Questions", *Banner Engineering*. [Online]. Available: https://www.bannerengineering.com/my/en/company/expert-insights/ultrasonic-sensors-101.html. [Accessed: 03- Mar- 2021].

[4]"Densities of Materials", *Engineeringtoolbox.com*. [Online]. Available: https://www.engineeringtoolbox.com/density-materials-d_1652.html. [Accessed: 03- Mar- 2021]

[5]"Linear actuator", *En.wikipedia.org*. [Online]. Available: https://en.wikipedia.org/wiki/Linear_actuator. [Accessed: 03- Mar- 2021].

[6]R. Cowan, *Linear Actuators 101*. 2018.].

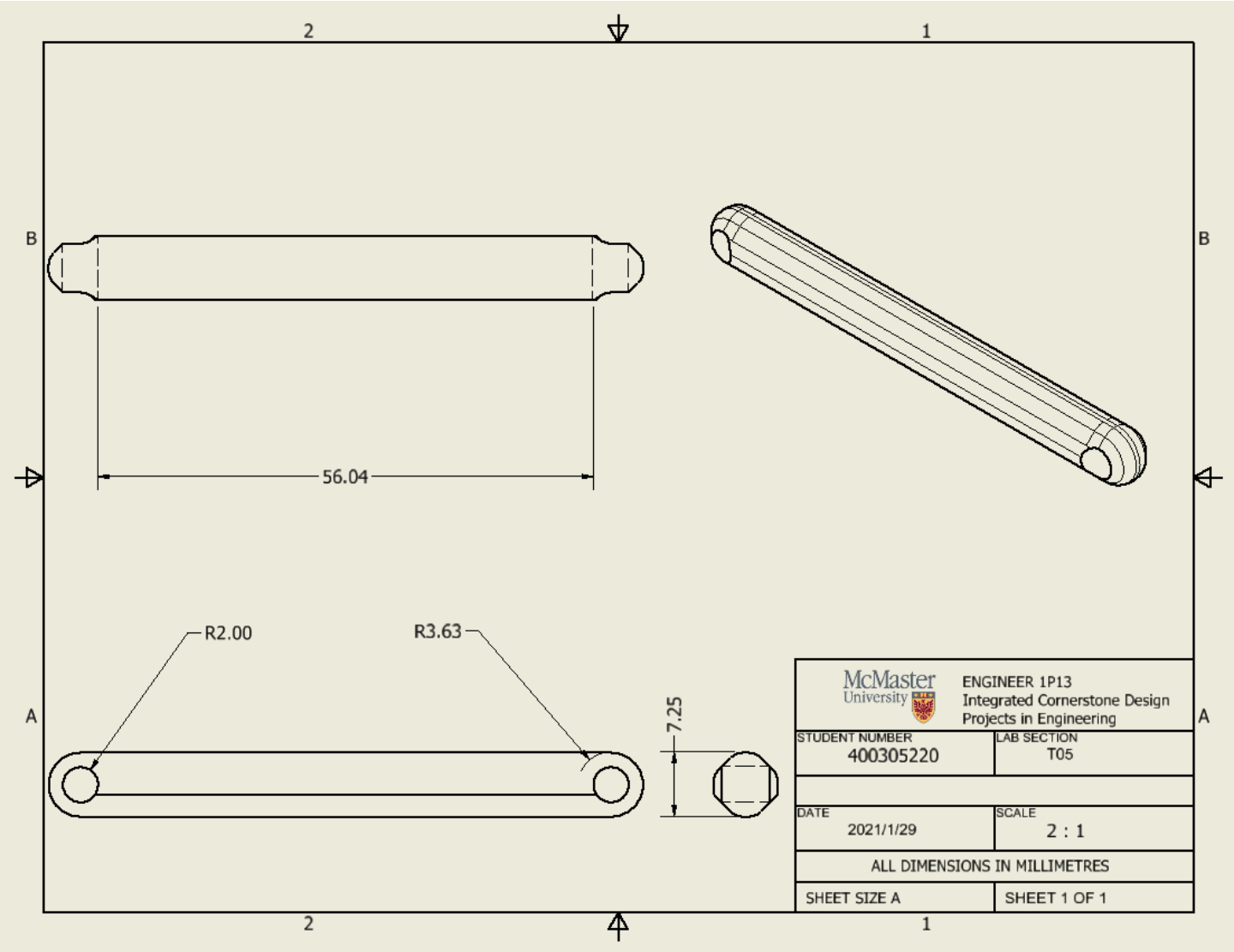
[7]"Rotary Actuator - an overview | ScienceDirect Topics", *Sciencedirect.com*. [Online]. Available: https://www.sciencedirect.com/topics/engineering/rotary-actuator. [Accessed: 03- Mar- 2021].

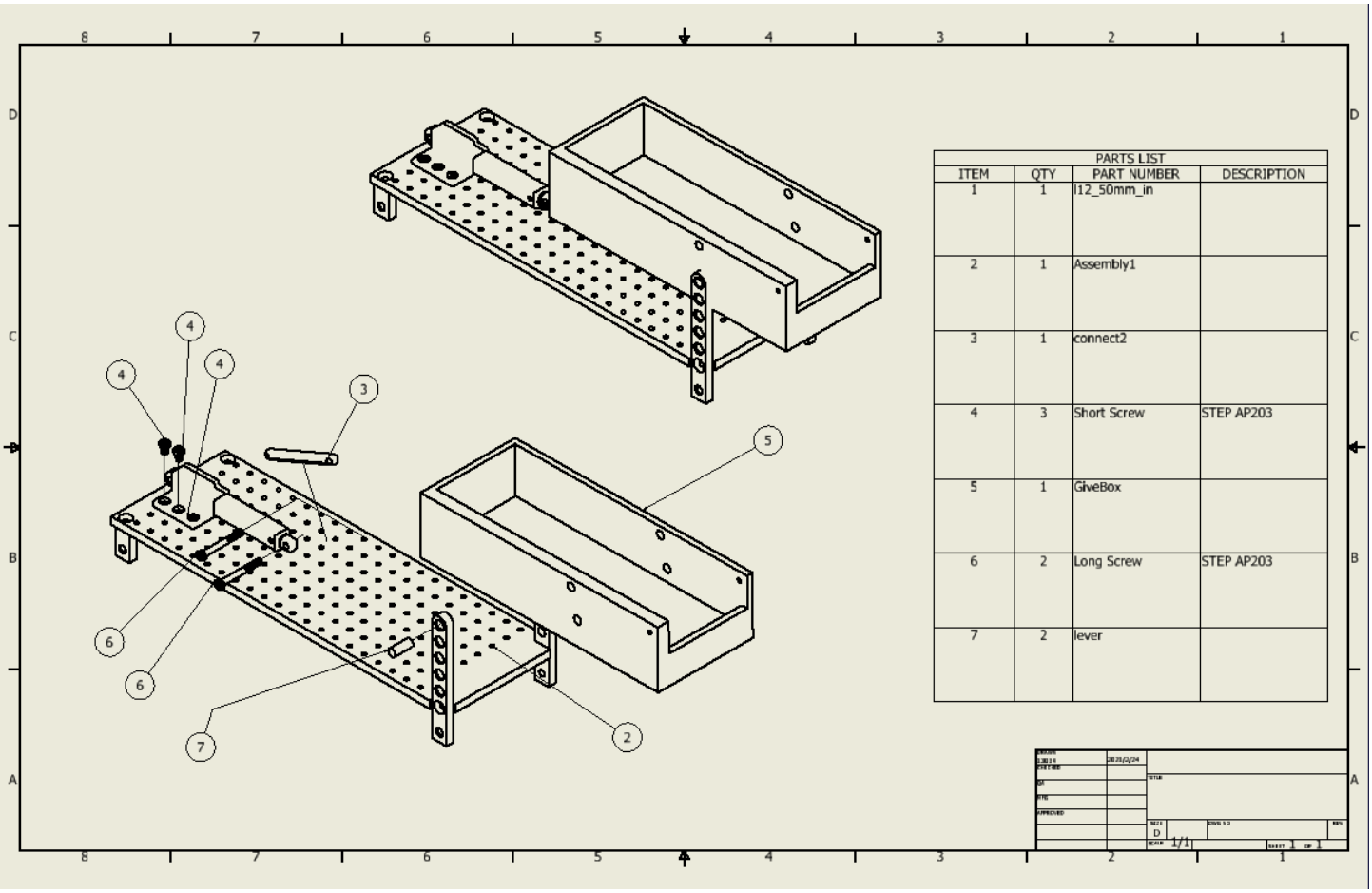
[8] Autodesk, “About the Grill Feature” Inventor [website].
Available: *https://knowledge.autodesk.com/support/inventor/learn explore/caas/CloudHelp/cloudhelp/2019/ENU/Inventor-Help/files/GUID-FA227D92-8FA9-4655-9411-D91F0487CB08-htm.html* Jul 28 2020 [Accessed: Mar. 4, 2021]]

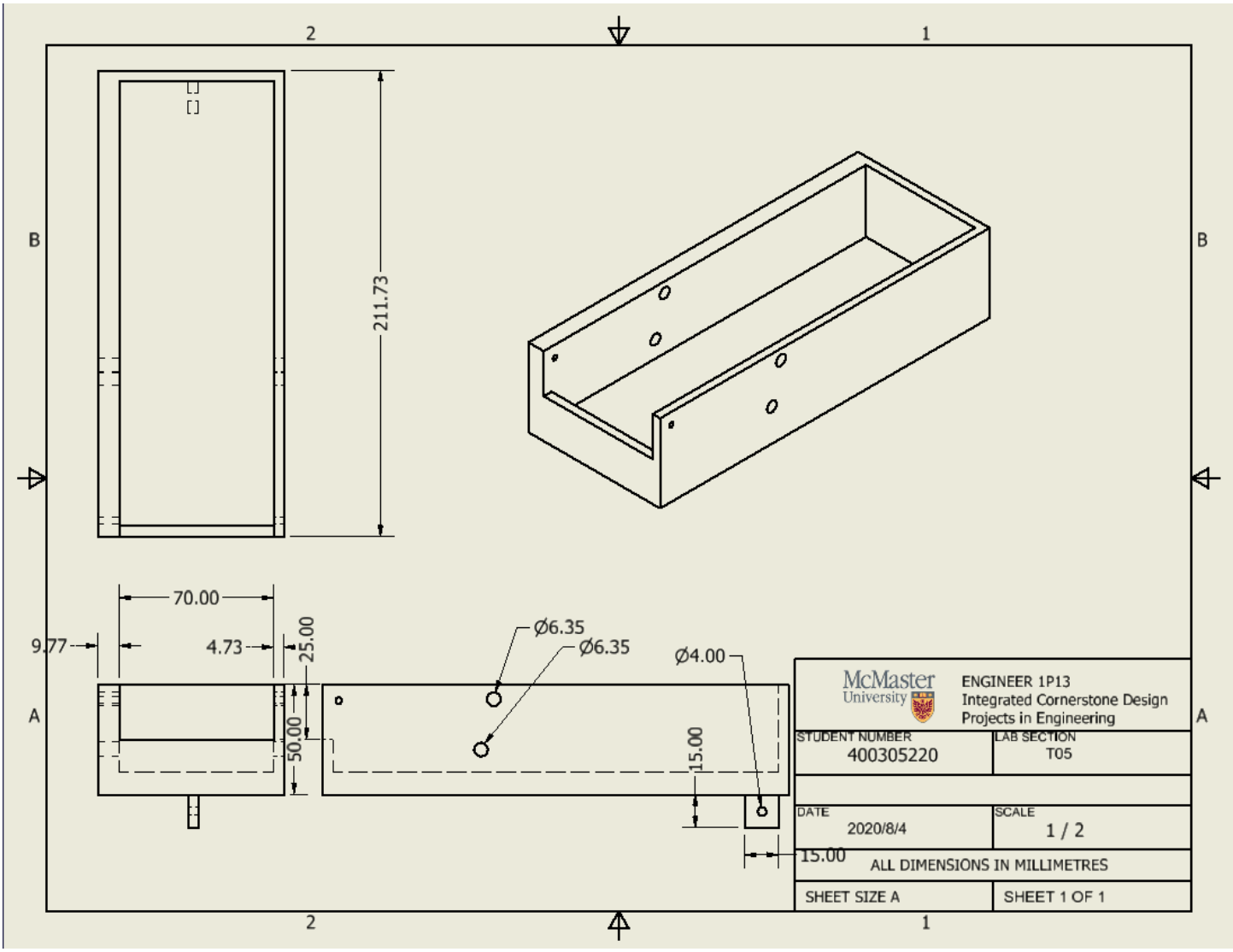
[9] Ansys Granta EduPack software, Granta Design Limited, Cambridge, UK, 2021 (www.grantadesign.com)

[10] "Engineering Essentials: Rotary Actuators", *Hydraulics & Pneumatics*. [Online]. Available: https://www.hydraulicspneumatics.com/fluid-power-basics/motors-actuators/article/21882753/engineering-essentials-rotary-actuators. [Accessed: 03- Mar- 2021].

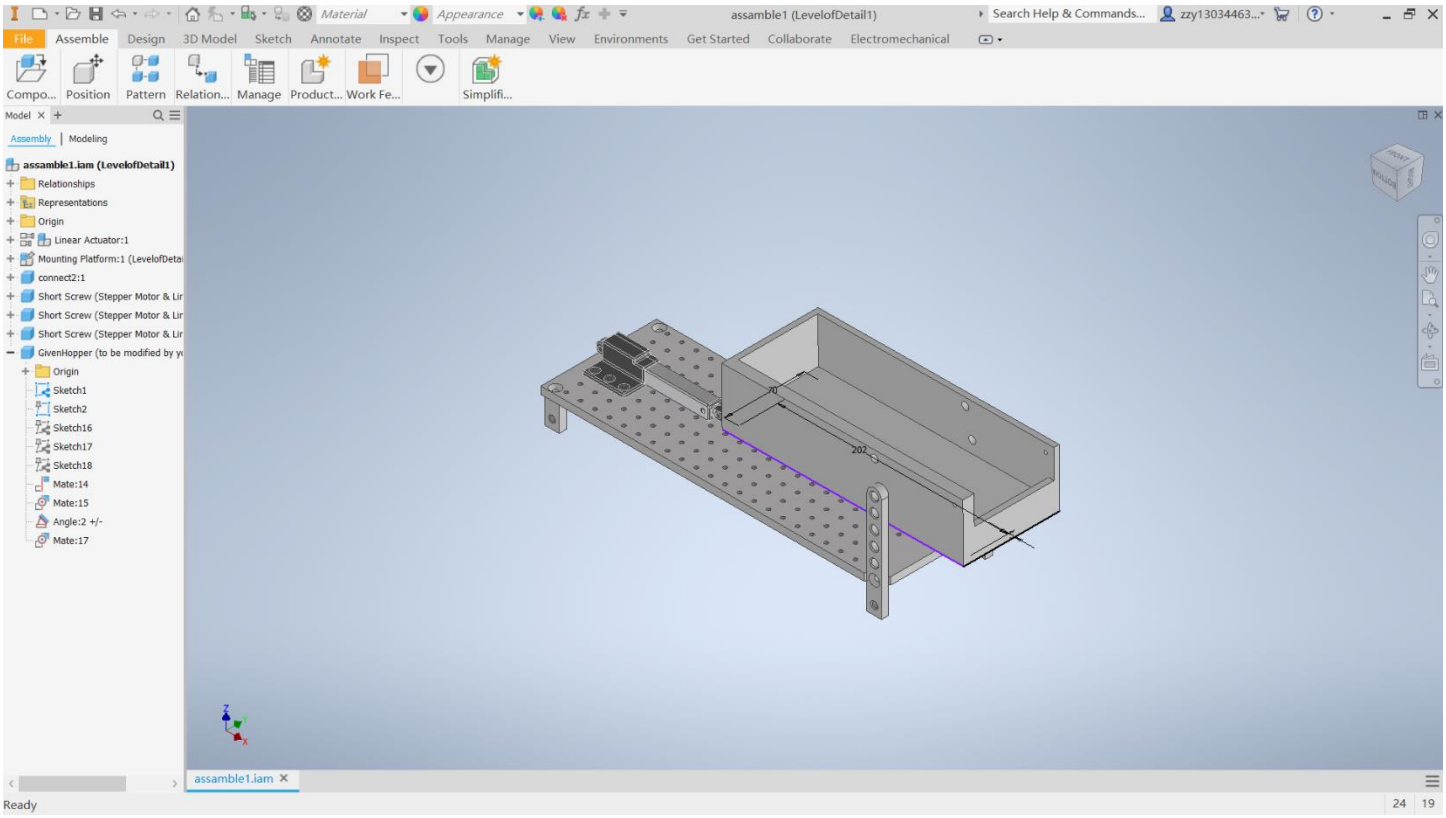
Appendix A: Fully-dimensioned Engineering Drawings

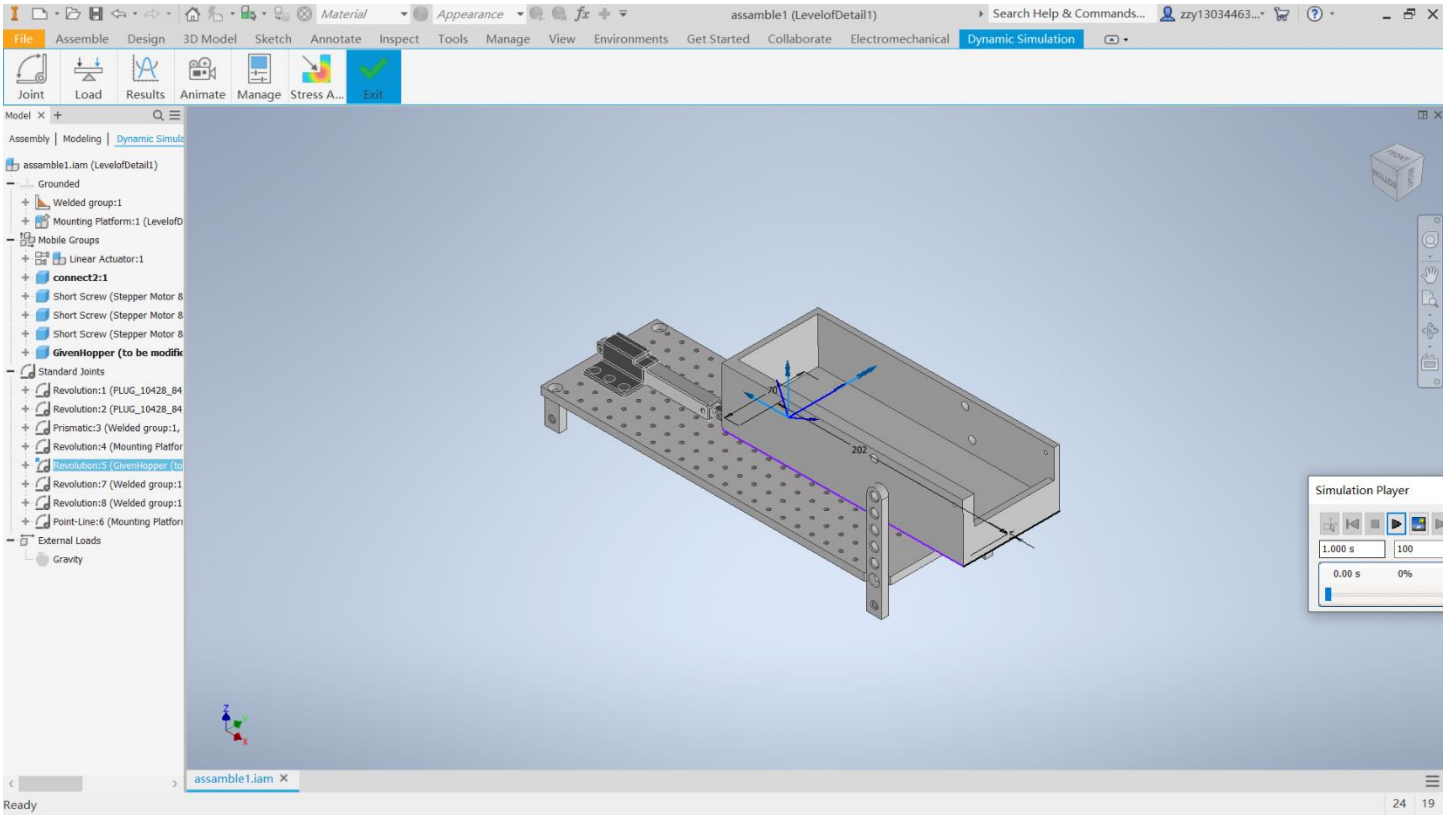



PARTS LIST
ITEM QTY PART NUMBER DESCRIPTION
1 1 l12_50mm_in
2 1 Assembly1
3 1 connect2
4 3 Short Screw STEP AP203
5 1 GiveBox
6 2 Long Screw STEP AP203
7 2 lever
1/1

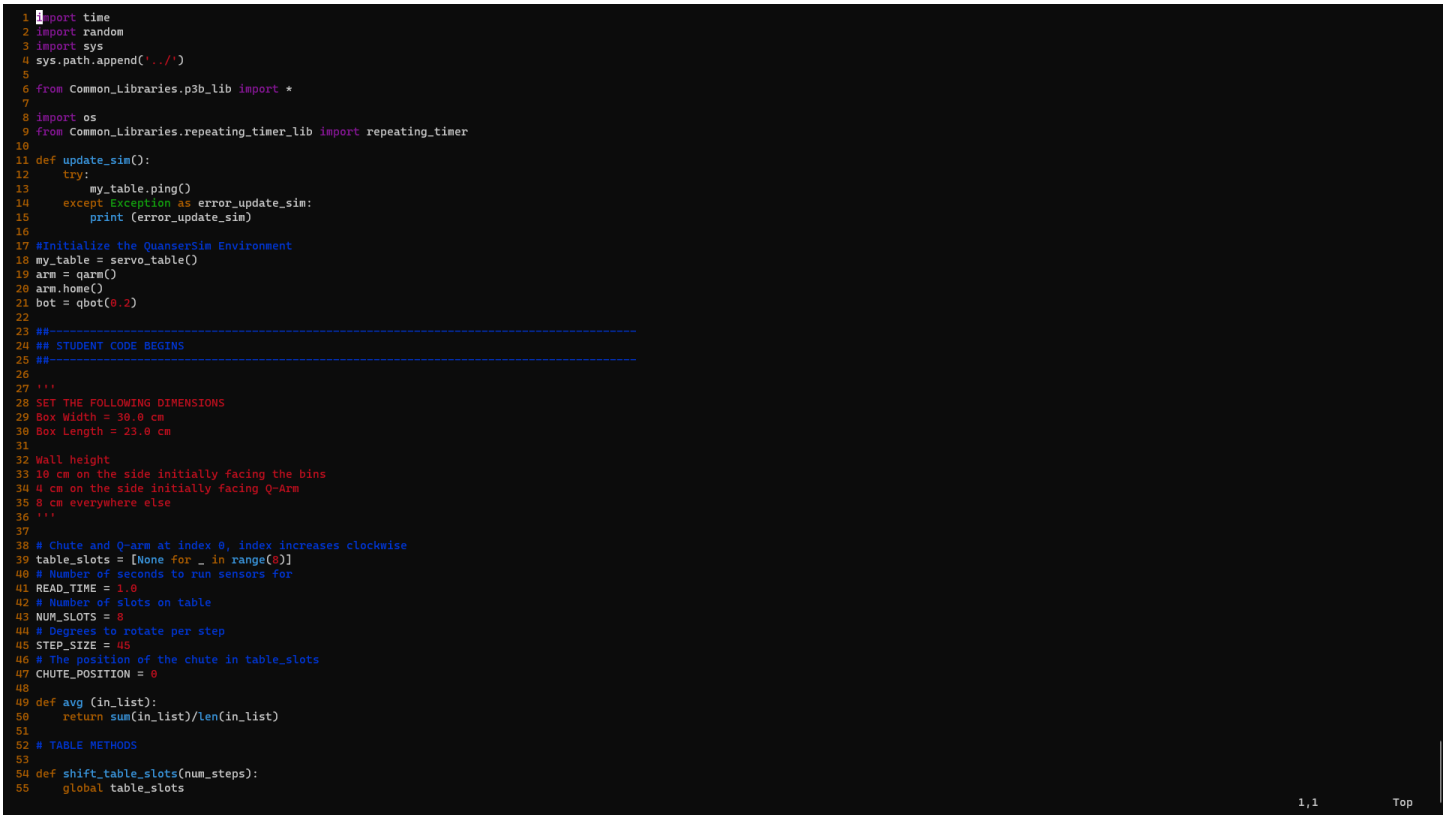

211.73
70.00
9.77
4.73
25.00
50.00
Ø6.35
Ø6.35
Ø4.00
15.00
15.00
McMaster University
ENGINEER 1P13
Integrated Cornerstone Design
Projects in Engineering
STUDENT NUMBER
400305220
LAB SECTION
T05
DATE
2020/8/4
SCALE
1 / 2
ALL DIMENSIONS IN MILLIMETRES
SHEET SIZE A
SHEET 1 OF 1

Appendix B: Screenshots of Solid Model





Appendix C: Screenshots of Computer Program



```
import time
import random
import sys
sys.path.append('../')

from Common_Libraries.p3b_lib import *

import os
from Common_Libraries.repeating_timer_lib import repeating_timer

def update_sim():
    try:
        my_table.ping()
    except Exception as error_update_sim:
        print (error_update_sim)

#Initialize the QuanserSim Environment
my_table = servo_table()
arm = qarm()
arm.home()
bot = qbot(0.2)

##-------------------------------------------------------------------------------------
## STUDENT CODE BEGINS
##-------------------------------------------------------------------------------------

'''
SET THE FOLLOWING DIMENSIONS
Box Width = 30.0 cm
Box Length = 23.0 cm

Wall height
10 cm on the side initially facing the bins
4 cm on the side initially facing Q-Arm
8 cm everywhere else
'''

# Chute and Q-arm at index 0, index increases clockwise
table_slots = [None for _ in range(8)]
# Number of seconds to run sensors for
READ_TIME = 1.0
# Number of slots on table
NUM_SLOTS = 8
# Degrees to rotate per step
STEP_SIZE = 45
# The position of the chute in table_slots
CHUTE_POSITION = 0

def avg (in_list):
    return sum(in_list)/len(in_list)

# TABLE METHODS

def shift_table_slots(num_steps):
    global table_slots
                                                                    1,1           Top
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    new_table_slots = [None for _ in range (NUM_SLOTS)]
    for i in range(NUM_SLOTS):
        new_table_slots[i] = table_slots[ (i - num_steps) % 8 ]

    table_slots = new_table_slots

def rotate_steps(num_steps):
    if num_steps > 0:
        shift_table_slots(-num_steps)
        my_table.rotate_table_angle(STEP_SIZE*num_steps)
    elif num_steps < 0:
        print("num_steps must be >= 0")


def rotate_to (from_index, to_index):
    if from_index > to_index:
        rotate_steps(from_index - to_index)
    elif to_index > from_index:
        rotate_steps(8 - (to_index - from_index))

def dispense(container_id):
    # Keep track of container info
    table_slots[0] = my_table.container_properties(container_id)
    # Drop container
    my_table.dispense_container()

def dispense_random_container():
    dispense(random.randint(1,6))

# Returns True if the table has no empty slots, False otherwise
def is_table_full():
    return not (None in table_slots)

# Fill all empty slots in the table with containers
def fill_table():
    while None in table_slots:
        index = table_slots.index(None) # Only need to search forward as table only turns clockwise
        rotate_to(index, CHUTE_POSITION)
        dispense_random_container()
        print(table_slots)

# Returns the determined target bin and the number of containers the q-arm needs to pick up
def choose_next_bin():
    _bins = [], [], [], []
    for i in range(NUM_SLOTS):
        # Get bin id number of the current container
        container_target_bin = int(table_slots[i][2][-1])
        _bins[container_target_bin-1].append(i)

    target_bin_id = "Bin0" + str(_bins.index(max(_bins, key=len))+1)
    return target_bin_id, min(3, len(max(_bins, key=len)))

# Returns the table_slots index of the next container going to target_bin
def choose_next_containers(target_bin_id, num_containers):
                                                                                    56,0-1        30%
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```
    container_positions = []
    total_mass = 0
    MAX_MASS = 90
    for i in range(NUM_SLOTS):
        total_mass += table_slots[i][1]
        if len(container_positions) >= num_containers:
            return container_positions
        if table_slots[i][2] == target_bin_id:
            if total_mass > MAX_MASS:
                break
            container_positions.append(i)
        print(container_positions)
    return container_positions

def positions_to_movements(positions):
    net = 0
    movements = positions.copy()
    for i in range(len(positions)):
        movements[i] -= net
        net += movements[i]
    return movements

# Q-ARM METHODS

HOME = 0.4064, 0.0, 0.4826

# Moves the arm to home position without releasing the gripper
def arm_home_position_only():
    arm.move_arm(HOME[0], HOME[1], HOME[2])

# Grabs a container, starting from the home position, ends with Qarm at table, gripping a container
def grab_container():
    arm.rotate_elbow(-35)
    arm.rotate_shoulder(60)
    arm.control_gripper(45)
    print(arm.effector_position())

# Starts from home position, loads container onto Qbot
def load_container(container_index):
    rotation = 0
    if container_index == 1:
        target_position = -0.0841, -0.4772, 0.3653
        #target_position = -0.1841, -0.4772, 0.3653
    if container_index == 2:
        target_position = 0.0841, -0.4772, 0.3653
        #target_position = -0.0241, -0.4772, 0.3653
    if container_index == 3:
        target_position = 0.0, -0.3739, 0.3769
        #target_position = -0.10, -0.3739, 0.3769
    arm_home_position_only() # Move to home position without dropping container
    arm.rotate_elbow(-45)
    arm.move_arm(*target_position) # Unpack x,y,z from target_position
    table_slots[CHUTE_POSITION] = None # Remove the container from table_slots

    arm.control_gripper(-45)
                                                                                    111,1         60%
```

```python
    arm.rotate_shoulder(-30)
    arm.home()
    print(arm.effector_position())


# Q-BOT METHODS

# Assumes there's a container in the hopper, and goes to specified bin
def transfer_container(bin_id):
    ultrasonic_reading = bot.read_ultrasonic_sensor(bin_id)
    while ultrasonic_reading > ULTRASONIC_THRESH:
        num_lost_lines, target_velocity = bot.follow_line(0.5)
        bot.forward_velocity(target_velocity)

        ultrasonic_reading = bot.read_ultrasonic_sensor(bin_id)
        print(ultrasonic_reading)

def deposit_container():
    linear_dump()
    #bot.dump()

def linear_dump():
    angle = 120
    duration = 1
    for i in range(angle):
        bot.rotate_actuator(i)
        time.sleep(duration/angle)
    time.sleep(1)
    for i in range(angle, 0, -1):
        bot.rotate_actuator(i)
        time.sleep(duration/angle)
    print("dumped")

def return_home():
    initial_lost_lines, target_velocity = bot.follow_line(0.5)
    num_lost_lines = initial_lost_lines

    while num_lost_lines - initial_lost_lines == 0:
        num_lost_lines, target_velocity = bot.follow_line(0.5)
        bot.forward_velocity(target_velocity)
        print(num_lost_lines)
    bot.rotate(190)

# How close to a bin you must be before you stop
ULTRASONIC_THRESH = 0.11

bot.activate_actuator()
bot.activate_ultrasonic_sensor()

while True:
    print(table_slots)
    fill_table()
    _bin_id, num_containers_targeting_bin = choose_next_bin()
    container_positions = choose_next_containers(_bin_id, num_containers_targeting_bin)
    num_containers = len(container_positions)
```

```python
    movements = positions_to_movements(container_positions)
    print(table_slots)
    print(_bin_id, num_containers, container_positions)
    print(movements)
    for i in range(num_containers):
        rotate_steps(movements[i])
        grab_container()
        load_container(i+1)
    transfer_container(_bin_id)
    deposit_container()
    return_home()

##-----------------------------------------------------------------------------------------
## STUDENT CODE ENDS
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update_thread = repeating_timer(2,update_sim)
```