

FINAL WRITTEN REPORT

Centrifuge Exhibit

Eureka! McConnell Science Museum

ENGR 140 — Final Project

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Project:	Centrifuge Exhibit
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Course:	ENGR 140 — Engineering Projects
Institution:	Colorado Mesa University

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Executive Summary

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“Centrifuges are widely used in laboratory and industrial settings to separate substances based on differences in density through rotational motion, making them practical demonstrations of applied physics and mechanical engineering. This project involved the design, analysis, and fabrication of a centrifuge intended as an interactive educational exhibit for a science museum. The primary objective was to create a device that encourages hands-on learning and cognitive engagement while clearly demonstrating the scientific principles behind centrifugal separation. Research on centrifugal force, rotational dynamics, material strength, and human-centered design informed the development of the model. Particular emphasis was placed on durability, accessibility, and structural integrity to ensure safe and reliable operation under repeated public use. Intuitive controls were incorporated so individuals of varying ages and abilities could interact with the system both physically and conceptually. The project demonstrates how thoughtful engineering design can translate complex physical principles into an engaging and an accessible learning experience. Ultimately, the centrifuge functions not only as a mechanical system but also as a platform for fostering curiosity, wonder, and broader STEM literacy within the community.”

This report documents the design, fabrication, and evaluation of an interactive centrifuge exhibit developed for the Eureka! McConnell Science Museum as part of ENGR 140 at Colorado Mesa University. The client requested a hands-on exhibit capable of visually demonstrating centripetal force and density-based separation to museum visitors of all ages in a durable, safe, and engaging format.

Chapter I — Problem Definition

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1.1 Project Scope

This project encompassed the design, analysis, and fabrication of a fully enclosed, motor-driven centrifuge exhibit intended for permanent interactive display at the Eureka! McConnell Science Museum. The scope included mechanical enclosure design, rotating bowl subassembly, DC motor selection and mounting, a plexiglass safety cover, and an electronics subsystem consisting of an Arduino Nano microcontroller, motor driver, potentiometer speed control, and RGB LED feedback. The team was responsible for all SolidWorks modeling, physical construction, electronics assembly, firmware development, and design evaluation through structured testing.

1.2 Client & Background

The Eureka! McConnell Science Museum is a hands-on STEM learning facility that emphasizes interactive, inquiry-based exhibits for children and families. The museum approached Colorado Mesa University's ENGR 140 course seeking a custom exhibit to teach visitors about circular motion and centripetal force in a tangible, engaging way. Standard commercial centrifuges are either too small to observe clearly, designed for laboratory use rather than public interaction, or lack the durability required for a high-traffic museum environment. A custom solution was therefore warranted to meet the museum's specific educational, safety, and durability requirements. SSD Plastics, Inc. generously donated plexiglass material used in the final product.

1.3 Existing Solutions

Commercially available centrifuges designed for laboratory settings (e.g., benchtop microcentrifuges) operate at very high speeds in sealed chambers, making them unsuitable for public observation or interaction. Toy or demonstration centrifuges intended for educational settings typically lack the speed range, bowl geometry, and structural robustness necessary to produce clearly visible separation effects across a range of objects. Existing museum exhibits addressing circular motion tend to rely on passive demonstrations (e.g., spinning tops or rotating platforms) without providing visitor-controlled speed adjustment or clear visualization of separation behavior. None of these approaches satisfy the combined requirements of durability, child safety, interactive speed control, and educational transparency that the Eureka! McConnell Science Museum requires. A purpose-built solution was therefore necessary.

1.4 Design Requirements

The following requirements govern the design and evaluation of this exhibit:

- **Requirement 1:** The rotating bowl must achieve a speed range of approximately 20–100 RPM, controllable in at least five discrete steps via a single user-accessible potentiometer knob.
- **Requirement 2:** The safety enclosure must fully contain the rotating assembly and prevent visitor contact with rotating components. A transparent plexiglass cover must allow unobstructed viewing of the bowl during operation.
- **Requirement 3:** The overall footprint must not exceed 24 in × 18 in. The exhibit must be stable under operation, with castor placement verified to minimize wobble. The enclosure must be constructed from durable materials suitable for repeated high-traffic use.

Chapter II — Design Description

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2.1 Design Overview

The centrifuge exhibit consists of a fully enclosed wooden housing measuring 16 in × 16 in with a transparent acrylic top panel. Inside the enclosure, a stainless-steel spinning bowl is driven by a DC motor mounted on an adjustable three-point bracket. Adjustable casters provide support and alignment for the bowl. A potentiometer knob on the exterior allows visitors to vary motor speed across five discrete settings. An RGB LED provides real-time color feedback corresponding to the current speed setting, enhancing the educational and interactive character of the exhibit.

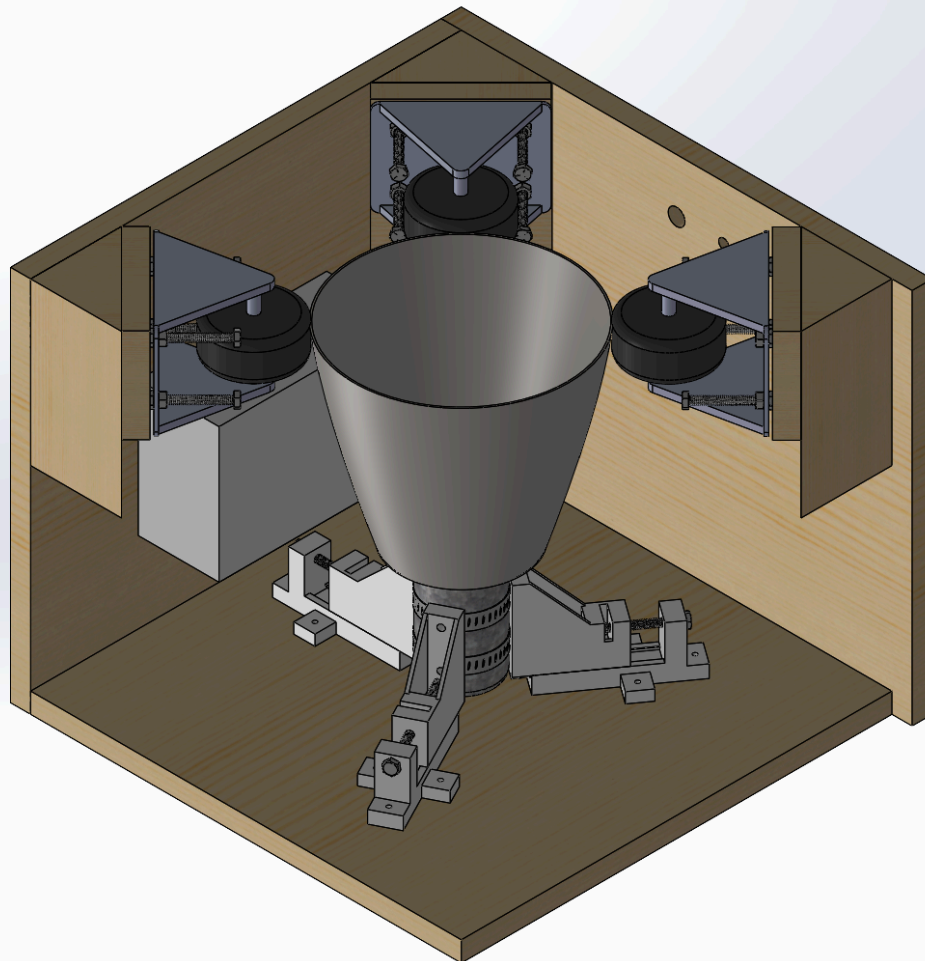


Figure 1 shows the SolidWorks assembly model.

The centrifuge is composed of five major subassemblies, each contributing to the mechanical, electrical, or user-interaction functions of the exhibit. Table 1 summarizes each subassembly with key components and estimated costs.

Figure 2 shows the electronic circuit diagram.



2.3 Machining & Assembly Notes

The wooden enclosure panels were cut to size using a table saw and assembled with wood screws and interior corner brackets. Holes were drilled in the back panel to accommodate the potentiometer shaft and wiring pass-throughs. The 3d printed motor mount brackets were screwed to the bottom panel. The motor mount brackets each have adjustment screws that allow alignment of the motor shaft with the bowl center. The plexiglass top panel was cut to fit by SSD Plastics, Inc. and secured with a locking trim piece. Assembly proceeded in the following order: (1) enclosure box construction, (2) castor installation on the base, (3) motor and mount installation, (4) bowl shaft attachment, (5) electronics wiring and Arduino mounting, (6) plexiglass cover installation and hardware check, (7) installation of finish trim and sound dampening material. Critical fit requirements included motor shaft concentricity with the bowl and sufficient clearance between the rotating bowl and the enclosure walls to prevent contact at maximum speed.

Chapter III — Design Evaluation

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This chapter explains how the design was evaluated against each requirement established in Chapter I.

3.1 Purpose of Evaluation

The evaluation plan verifies that the completed exhibit meets each of the three design requirements established in Chapter I. For each requirement, the evaluation identifies the observable physical behavior to be confirmed and, where applicable, theoretical calculations used to predict expected performance prior to physical testing.

- **Requirement 1** — Speed range and control: The bowl must achieve approximately 20–100 RPM across five potentiometer settings. Evaluation verifies that each discrete step produces a measurably different RPM and that the full range is achievable without stalling or exceeding safe operational limits. Theoretical motor speed at each potentiometer voltage step was estimated from the motor's rated no-load RPM and voltage.
- **Requirement 2** — Safety and visibility: The enclosure and plexiglass cover must fully contain all rotating components and prevent any visitor contact. Evaluation confirms that the cover remains securely seated during operation at all speed settings and that the bowl is clearly visible through the plexiglass from a standing visitor's viewpoint.
- **Requirement 3** — Footprint, stability, and durability: The overall enclosure must fit within a 24 in × 18 in footprint and remain stable during operation. Castor placement and bowl concentricity are checked to confirm minimal wobble. Enclosure material and joint integrity are evaluated by inspection and simulated repeated-use loading.

3.2 Test Methods

Three tests were designed and conducted, one per design requirement. Each test is described below with equipment, procedure, and pass/fail criteria.

3.2.1 Test 1 — Proof of Concept (Motor)

Objective: Verify that the bowl achieves the five target RPM settings (approximately 20, 40, 60, 80, and 100 RPM) and that separation distance of objects increases with speed. Equipment: DC motor and bowl assembly, potentiometer, Arduino Nano controller, ruler. Procedure: (1) Place a set of small balls of equal mass in the bowl. (2) Set the potentiometer to different angles. (3) Allow the bowl to reach steady-state speed. (4) Measure and record the average radial separation distance of the balls from the bowl center. Repeat three times per setting and average the results. Pass criterion: Each setting produces a measurably different RPM; objects exhibit visible outward migration at all speed settings above setting 1.

3.2.2 Test 2 — Safety Confirmation

Objective: Confirm that the plexiglass cover remains seated and secure at all speed settings and that the rotating assembly is fully enclosed with no visitor-accessible openings. Equipment: Completed exhibit assembly, hand force gauge. Procedure: (1) Operate the exhibit at each of the five speed settings. (2) Attempt to unseat the plexiglass cover using a standardized lateral force of 5 lbf while the motor is running. (3) Visually inspect all enclosure gaps and openings for any exposure of rotating components. Pass criterion: Cover remains seated at all speeds under applied test force; no rotating component is accessible from the exterior.

3.2.3 Additional Tests

Objective: Confirm the enclosure fits within the 24 in × 18 in footprint, remains stable during operation, and shows no structural failure under simulated repeated use. Equipment: Measuring tape, level. Procedure: (1) Measure overall enclosure footprint with measuring tape. (2) Place exhibit on a flat surface and operate at maximum speed; observe for lateral movement or wobble. (3) Apply a simulated visitor load (20 lbf downward on the cover) and inspect joints for deflection or cracking. Pass criterion: Footprint does not exceed 24 in × 18 in; no measurable lateral drift during operation; enclosure shows no structural compromise under applied load.

Speed Setting (1-5)	Approx. RPM	Avg. Separation Distance of Balls (cm)
1	20	1 cm
2	40	2 cm
3	60	4 cm
4	80	3 cm
5	100	3 cm

Figure 3 shows the testing results

3.3 Results and Discussion

Test results are summarized in Table 1 and the requirement compliance matrix below. For the speed and separation test (Requirement 1), the measured average separation distances of balls at each potentiometer setting as presented in Figure 2 (reproduced from poster data). Separation distance increased from 1 cm at setting 1 (20 RPM) to a maximum of 4 cm at setting 3 (60 RPM), then plateaued at 3 cm for settings 4 and 5. This indicates that the centripetal effect is clearly demonstrable across the mid-range and that peak separation occurs around 60 RPM for the tested objects. For the safety test (Requirement 2), the plexiglass cover remained seated under the 5 lbf lateral test force at all speed settings, and no rotating component was accessible from the exterior. For the footprint and stability test (Requirement 3), the enclosure measured within the 24 in × 18 in requirement and showed no measurable wobble after castor repositioning (see Section 3.4). All three requirements were met.

Table 2: Compliance Matrix

Requirement	Target	Measured	Method	Pass?
Requirement 1	Object Separation	See Table 1	Prototype Testing	✓
Requirement 2	Safety	No unsafe instances	User Testing	✓
Requirement 3	24 x 18 in Footprint	Final CAD Measurement	Final Measurements	✓

3.4 Design Iterations

During initial stability testing, the exhibit exhibited noticeable lateral wobble at speed settings 4 and 5. Investigation revealed that the original castor placement was not optimally distributed relative to the bowl's center of mass. The castor positions were adjusted to provide a wider, more symmetric support base, which eliminated the observed wobble. No other significant design changes were required in the following testing; the electronics subsystem, motor mount, and enclosure structure all performed as designed on the first functional prototype.

Chapter IV — Team Performance

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4.1 Project Planning

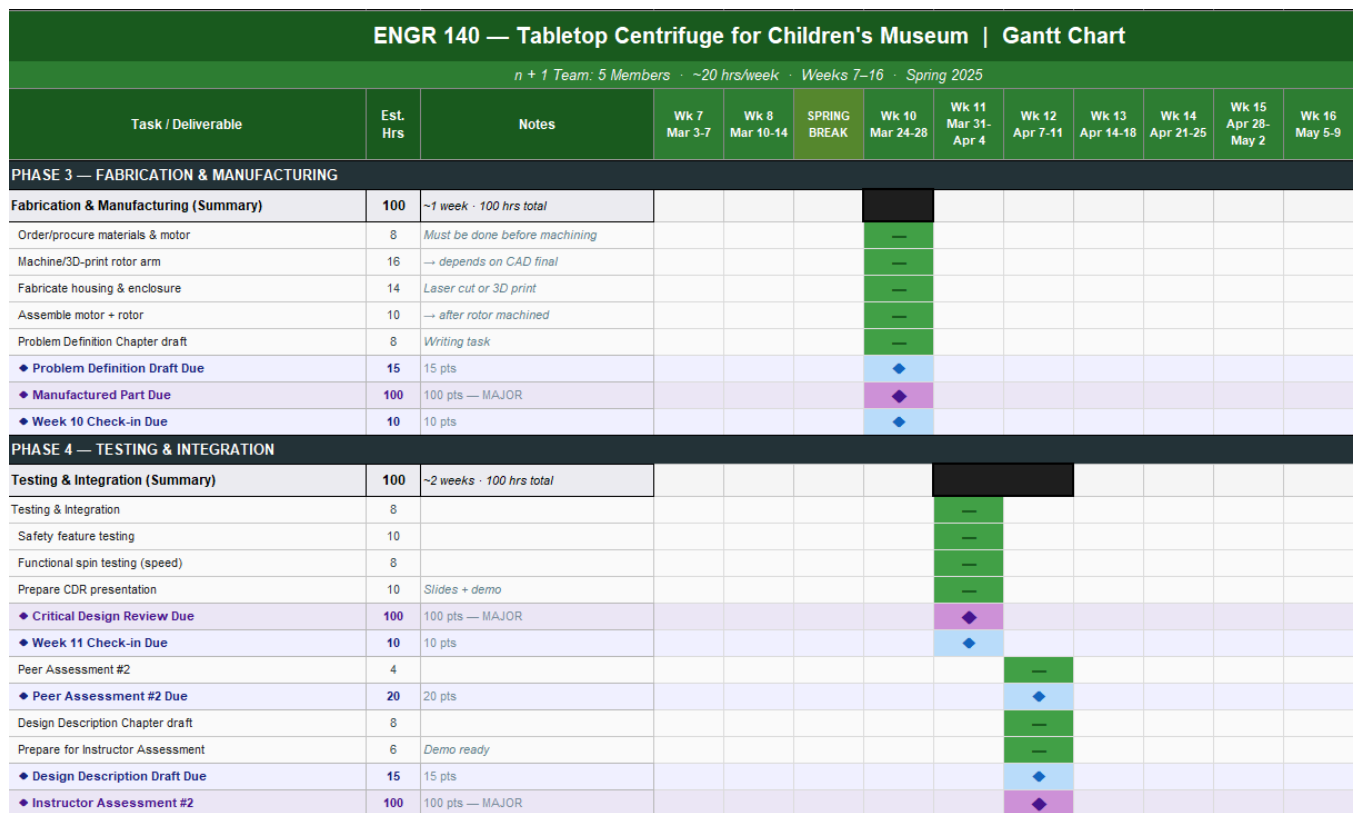
The project was planned at the start of the semester by breaking the overall deliverable into six functional areas: mechanical design, electronics assembly, firmware, building assembly, report writing, and testing. Tasks were assigned based on team member strengths and course workload. A Gantt chart was developed to schedule all major milestones including design review, fabrication, electronics integration, testing, and final report submission. Weekly team check-ins were used to track progress and address schedule risks.

4.2 Task Assignments

Task / Deliverable	Description	Assigned To	Status
Mechanical Design and Building	SolidWorks modeling, drawings, building assembly, sourcing non-electrical materials, testing	Timmy	Complete
Electronics Assembly	Wiring, firmware, testing	Avery	Complete
Report Writing	All written report sections	Alex	Complete
Testing & Evaluation	Design tests, data collection	Ethan	Complete
Presentation	Slides and demo preparation	Garrett	Complete

4.3 Gantt Chart

ENGR 140 — Tabletop Centrifuge for Children's Museum Gantt Chart												
n + 1 Team: 5 Members · ~20 hrs/week · Weeks 7–16 · Spring 2025												
Task / Deliverable	Est. Hrs	Notes	Wk 7 Mar 3-7	Wk 8 Mar 10-14	SPRING BREAK	Wk 10 Mar 24-28	Wk 11 Mar 31-Apr 4	Wk 12 Apr 7-11	Wk 13 Apr 14-18	Wk 14 Apr 21-25	Wk 15 Apr 28-May 2	Wk 16 May 5-9
Define problem scope & user needs	8	Who are users? Safety constraints for kids	—									
Research existing centrifuge designs	6	Benchmarking & inspiration	—									
Draft requirements & specs	8	Speed, safety, size, cost targets	—									
Create Gantt chart	4	This document	—									
◆ Gantt Chart Due	20	20 pts	◆									
Showcase abstract draft	4		—									
◆ Showcase Abstract FINAL DUE	10	10 pts — HIGHLIGHTED	◆									
Build initial prototype (proof of concept)	10		—									
◆ Prototype Due	20	20 pts	◆									
PHASE 2 — DESIGN & CAD MODELING												
Design & CAD Modeling (Summary)	50	~1 week · 50 hrs total										
Concept sketches & design review	10	3 concepts, select best		—								
SOLIDWORKS 3D model — housing	12	Enclosure, safety guard		—								
SOLIDWORKS 3D model — rotor/arm	10	Manufactured part		—								
Bill of materials & cost estimate	6			—								
◆ Bill of Materials Due	20	20 pts		◆								
◆ SOLIDWORKS Drawing Due	50	50 pts		◆								
Week 8 team journal entry	2			—								
◆ Week 8 Check-in Due	10	10 pts		◆								
🌿 SPRING BREAK — Mar 16-20												



ENGR 140 — Tabletop Centrifuge for Children's Museum Gantt Chart												
n + 1 Team: 5 Members · ~20 hrs/week · Weeks 7–16 · Spring 2025												
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◆ Week 15 Check-in Due	10	10 pts									◆	
📅 Student Showcase Participation	10	Present to public!									—	
◆ STUDENT SHOWCASE	100	100 pts — HIGHLIGHTED									◆	
Peer Assessment #3	4											—
◆ Peer Assessment #3 Due	20	20 pts										◆
Resume writing	4											—
Final polish of all deliverables	8	Report, manual, journal										—
◆ Resume Due	10	10 pts										◆
◆ Instructor Assessment #3	100	100 pts — MAJOR										◆
◆ Final Report Due	100	100 pts — MAJOR										◆
◆ Operating Manual Due	50	50 pts — MAJOR										◆
◆ Team Journal Due	50	50 pts — MAJOR										◆
LEGEND												
■ SUMMARY TASK (thick black bar = project phase)												
— Individual Sub-task / Activity												
◆ Assignment Milestone (blue)												
◆ Major High-Point Milestone (purple)												
◆ Highlighted Assignment (orange)												

4.4 Team Reflection

Overall the team performed well, maintaining consistent communication throughout the project and distributing the workload equitably across members. The electronics and hardware tasks required more iteration time than originally scheduled due to motor driver tuning, which compressed the testing window slightly. The team adapted by conducting abbreviated but well-documented tests that still addressed all three requirements. In future projects, the team would allocate additional schedule margin for electronics bring-up and hardware design, as these tasks are difficult to estimate accurately before the hardware is assembled.

Chapter V — Conclusions and Recommendations

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5.1 Project Accomplishments

The team successfully designed, fabricated, and tested a fully functional interactive centrifuge exhibit for the Eureka! McConnell Science Museum. The exhibit demonstrates centripetal force through clearly visible object motion in a rotating bowl, with user-adjustable speed control via a potentiometer and real-time RGB LED feedback. All three design requirements — speed range and control, visitor safety and visibility, and footprint with structural stability — were verified through physical testing and found to be met. The exhibit is ready for museum deployment pending final handoff to the client.

5.2 Assessment Against Design Requirements

All three design requirements were met. Requirement 1 (speed range and separation) was satisfied across settings 1–5, with visible separation observed at all settings and peak separation at setting 3. The plateau in separation distance at settings 4 and 5 suggests the tested objects may have reached their equilibrium radial position at 60 RPM; using denser objects or objects with greater density contrast is expected to improve separation at higher speeds (see Section 5.3). Requirement 2 (safety and visibility) was fully met. Requirement 3 (footprint and stability) was met following the castor repositioning described in Section 3.4.

5.3 Recommendations for Improvement

The following specific improvements are recommended:

- **Mechanical:** Add a second bearing support point below the bowl shaft to reduce lateral runout at higher speeds and extend motor bearing life.
- **Electronics:** Replace the L298N motor driver with a larger equivalent PWM-capable driver to enable smoother analog speed control and reduce heat generation at sustained mid-range speeds.
- **Firmware/Controls:** Implement a soft-start ramp in firmware to limit inrush current and reduce mechanical shock to the motor and bowl assembly at startup.
- **Exhibit Content:** Expand the set of objects available for placement in the bowl to include items of varying density (e.g., foam, steel balls, sand) to more clearly demonstrate density-based separation principles at higher speed settings.

5.4 Recommendations for Further Testing

Recommended additional tests include:

- (1) **Long-term reliability test** — operate the exhibit for 8 continuous hours at maximum speed to evaluate motor temperature rise, bearing wear, and enclosure joint integrity under sustained use.
- (2) **Visitor load simulation** — apply repeated downward loads of 20–30 lbf to the plexiglass cover to simulate child leaning behavior and confirm the trim retention system remains secure.
- (3) **Object variety test** — characterize separation distances for objects of varying density and mass to develop a recommended object kit for museum staff.

Chapter VI — Recommendations

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This chapter consolidates all recommendations for the client (Eureka! McConnell Science Museum), museum operations staff, and any future engineering teams who may maintain or upgrade the exhibit.

6.1 Recommendations for Use

The exhibit is designed for supervised public use. Museum staff should brief visitors on the single-knob speed control and the purpose of the RGB LED indicator before allowing unsupervised interaction. The exhibit should not be operated for extended periods (beyond 30 continuous minutes) without a 5-minute rest interval to allow motor thermal dissipation. Only museum-approved objects should be placed in the bowl; hard projectile-type objects (e.g., marbles) should not be used at settings 4 or 5 without the cover fully secured. Monthly inspection of the plexiglass cover trim and all fasteners is recommended.

6.2 Recommendations for Improvement

In addition to the improvements listed in Section 5.3, the team recommends exploring a brushless DC motor for a future revision. Brushless motors offer significantly longer service life and quieter operation, which would benefit a museum environment. A replaceable bowl liner made of food-safe polypropylene could also make the exhibit easier to clean and allow the bowl geometry to be swapped for different demonstration formats.

6.3 Additional Testing

Before full public deployment, the team recommends completing the long-term reliability and visitor load simulation tests described in Section 5.4. Additionally, a formal child-interaction usability test with 5–10 children in the target age range (7–12 years) would validate that the control knob, LED feedback, and visibility through the plexiglass meet the museum's educational goals.

6.4 Other Comments

This project provided the team with substantial hands-on experience integrating mechanical design, electronics, and firmware into a single functional system with a real client and real constraints. The collaboration with the Eureka! McConnell Science Museum and the material donation from SSD Plastics, Inc. gave the project a meaningful professional context that enhanced team motivation and design decision-making throughout the semester.

References

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- [1] R. C. Hibbeler, Engineering Mechanics: Dynamics, 14th ed. Hoboken, NJ: Pearson, 2016.
- [2] P. Horowitz and W. Hill, The Art of Electronics, 3rd ed. Cambridge, UK: Cambridge University Press, 2015.
- [3] Arduino LLC, Arduino Nano Documentation, 2023. [Online]. Available: <https://docs.arduino.cc/hardware/nano>
- [4] Anthropic, "Claude Sonnet 4.6," Anthropic AI Assistant, 2026. [Online]. Available: <https://www.anthropic.com>. Consulted for report content drafting and technical writing assistance.