MECH 202 Spring 2013 Competition Project : The Ornamentor (Updated 26 April 2013)

Your team is to design, fabricate, assemble, and compete with a working device that safely places an ornament on a hook and satisfies the competition rules below. Your team must also submit a report detailing your device and the process used to develop your design.

Time & Place

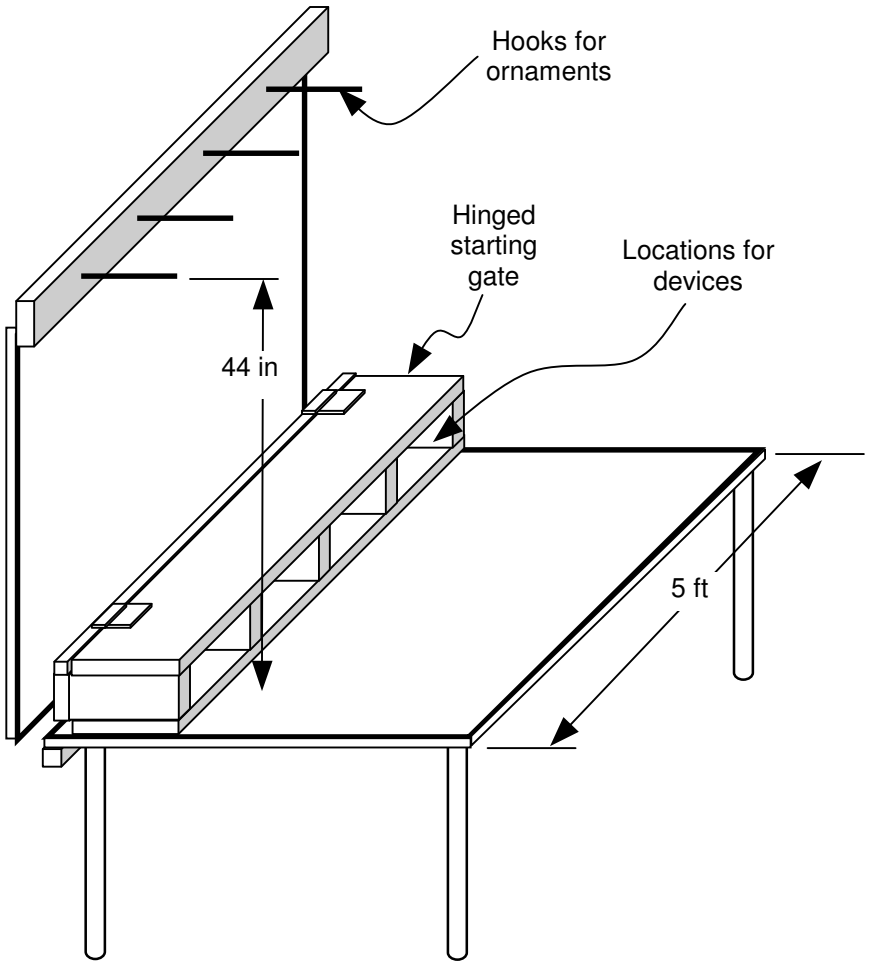
The competition will be on Saturday, April 27, in Behavioral Sciences Room 131.

- Your project report must be submitted as a PDF to the drop-box folder by 8am that day.
- Registration starts at 8:15am per the schedule shown in Appendix E.
- The competition starts at 9am.
- The competition takes most of the day. The finals are expected to occur between 2pm and 3pm.

Competition Overview

1. Your team is hired by "Ornamentors Inc" to design and build the most reliable and lightest weight device that autonomously expands, safely places a holiday ornament, and then collapses back into its initial location (a box measuring approximately 12"x12"x3.5 ") in less than 45 seconds.

2. Below is a conceptual (not to scale) drawing of the competition fixture. Appendix B provides additional sketches. Note, that your group should be taking their own measurements and designing your device to handle variability in the competition fixture.



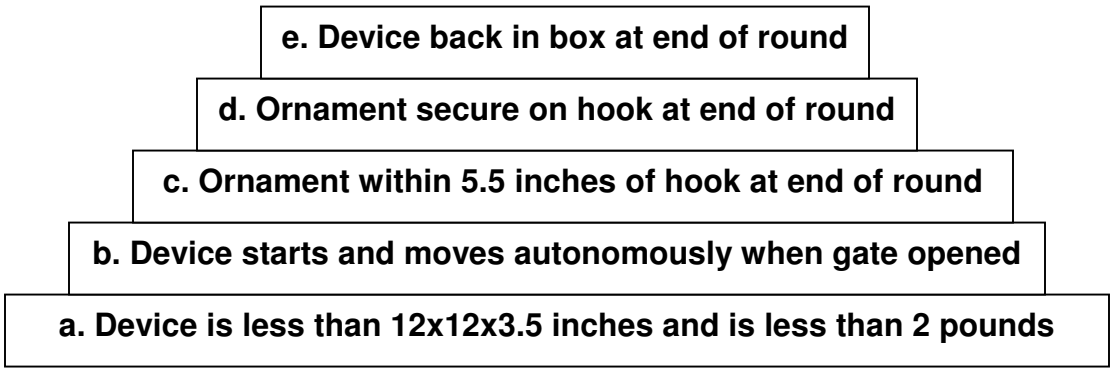
3. The TAs will keep this fixture locked, except during viewing times from now until competition day. Your team should schedule with the TAs to see and measure the fixture so you can use these

measurements to ensure that your device will work correctly on it. You are not allowed to place your device on the competition fixture until the first time you compete on April 27. Your group is encouraged to make its own test fixture to be used to develop and test your device.

4. The ornament is a foam "peace sign". We obtained the ones for the competition in the crafting department at Walmart, but they may not be easily available. Appendix B provides the key dimensions if you'd like to make something similar to test with. The TAs will also have samples of the ornament for you to measure.

Competition Objectives and Main Rules

5. The winning device in each round is determined based on: (i) the tasks completed during a 45-second round; (ii) safety in completing the tasks; and (ii) device weight. The hierarchy of tasks to be completed is shown below:



6. The safety requirements and their impact on competition results are as follows:
   a. Any device that does not pass its safety audit (which must occur with one of the TAs prior to noon on Friday, April 26) will not be allowed to compete. The safety audit can occur anytime during the week prior to the competition and should be scheduled with the TAs.
   b. Devices must stay in their "lanes". Each lane is defined as the vertical projection of their (approximately 12"x12") box to a height that extends one foot above the hook and the region up to 12 inches in front of the vertical projection of the box. Since the hook is approximately 44 inches above the table surface, this defines a lane as being 56 inches tall, 12 inches wide, and 24 inches deep. Any device that moves outside of its "lane" at any time during a round will be considered to have lost that round. Note that this also means that your device cannot touch the back of the fixture.
   c. Any device that damages the fixture or damages another device during a round will be eliminated from that round. If it is determined that the damage is accidental, then the device will be allowed to run in subsequent rounds if it has not lost two rounds. If the damage is determined to have been willfully incurred, the device will be eliminated from any subsequent competition.
   d. Any team whose device is damaged as a result of the actions of another device will be given a reasonable time (normally a maximum of 15 minutes) for the team to make repairs. That round will then be re-run with the device that caused the damage not included in the round.
   e. Any device that damages or drops its ornament will be considered to have caused a fatality. That device will lose the round and also will not be allowed to run in any subsequent rounds. Devices that cause fatalities in the real world generally can no longer get insurance.

7. Here is a more detailed definition of each of the five tasks:
   a. The entire device must fit in the starting location (a box approximately 12 inch x 12 inch x 3.5 inches) shown in the picture on the previous page. This includes space in this box for the ornament. We expect that each team will be placing their device into the starting box by sliding the device in through the front opening with the starting gate closed. The device must also weigh less than 2 lbs. Any devices that weigh over 2 pounds will be required to remove items before they are allowed onto the competition fixture.

b. When the starting gate lifts out of place, your device must automatically and autonomously lift the ornament. We recommend that you design your device to have some kind of a switch or trip mechanism that senses the movement of the starting gate to release a spring, start a motor, or otherwise start the motion of your device. Note that your team will not be near your device when it is supposed to start and you cannot have any type of a "remote control."
c. If your device successfully actuates, we will then determine the ornament is close to the hook at the end of the 45-second round. By close, we mean within one diameter of the ornament, which equals 5.5 inches. This will be a visual check by the TAs.
d. The next task is to securely place the ornament on the hook. To fulfill this requirement, the ornament must be hanging from the hook and your device must not be touching any part of the ornament or any part of the fixture near the hook at the end of the 45 second round.
e. The final task is for your device to completely collapse back into its 12x12x3.5 inch box. It will have fulfilled this requirement if the line judges (TAs) can see nothing sticking out when looking horizontally across the top of your box and looking across the open front of your box. Note specifically that your entire device (including any starting switch) must be below the upper surface of the box without the lid being closed. No part of your device can be protruding outside of the front of the box either. The TAs will probably use a visual method or something like a yardstick to verify that nothing is protruding. We recommend that you ensure that your device reliably has everything back in the box.

8. If more than one device in a round completes the same ~~number~~ tasks in the 45 seconds allowed without any safety violations, the device that had the lowest weight will be declared the winner of that round. The hierarchy is as follows:
Best: Devices that place the ornament and return completely to the box (all 5 tasks completed).
Next best: Devices that place the ornament and do not return completely to the box (4 tasks done).
Third best: Devices that place ornament within 5.5 inches of hook at end of 45 seconds (3 tasks).
Fourth best: Devices that started and moved when gate was opened (2 tasks).
Fifth best: Devices that met size and weight requirements, but did not start (1 task).
Worst: Devices that did not meet size and weight requirements (0 tasks).

9. If no devices start and move, the round will be run a second time. If during the second time no devices start and move, the lightest device in that round will be considered to have won that round.

Further Competition Details and Clarification

10. Other than teams that were completely eliminated from the competition due safety violations as mentioned earlier, the competition will be "double elimination" so each team will have at least two chances to participate. Details of how the heats and how the winners and losers move from round to round will be available prior to the day of the competition. Only the first place winners will advance to the next round. We will try to record which devices came in second, third, and fourth place and all tasks that each device accomplished, but will not use this for determining competition results.

11. Your device cannot touch any part of the fixture except:
a. the base of the table inside of your box;
b. the inside surfaces on the sides of your box;
c. the hook and the region near the hook vertically above the inside of your 12x12x3.5" box; and
d. your device can touch the underside of the lid at the start, but can't use significant force to do so. If your device causes the lid to shift position, which might affect other devices, it would be disqualified. If you use the opening of the lid to start your device, think about a reliable, low force or now force, way to do this. As mentioned previously, no part of your device should not intentionally touch any other device during the competition. If we can see that this contact with another device was intentional, your device will be eliminated.

12. Your device can weigh no more than 2 lbs.

13. You are encouraged to build your own test fixture. We deliberately made our fixture from standard low cost parts to facilitate duplication of the key elements for our testing. Some of the key parts used for the competition fixture are described in Appendix B.

14. Keep in mind that the components used to make the competition fixture will not be perfect or exactly like a test fixture that you might fabricate from the same parts. It is important that your device can tolerate these types of differences. This is and important aspect of having a robust design. Also note that you cannot place your device on the test fixture prior to the competition. You can take measurements. Every year there are devices that fail to operate due to dimensional differences between the competition fixture and the test fixtures built by students. This is your warning to make sure that you make a device that is tolerant of variations.

15. Your device can be made from any materials that you would like to use. However, you cannot use any energy storage method or device that might be deemed hazardous. Examples of hazardous energy storage devices include, but are not limited to:
    - Explosives, combustion processes, or highly exothermic reactions (such as model rockets).
    - A compressed fluid that might release too quickly
    - Anything deemed to be unnecessarily harmful to either the fixture or another competitor's device. This includes having motors that overheat, generate sparks, etc or wheels that leave a residue on the fixtures.

16. If your team is not willing to stand next to your device without protective clothing or safety glasses, your device will be considered hazardous! However, since some individuals are braver than others. The judges reserve the right to deem a device hazardous.

17. No human contact with the device is allowed at any time during the time from the start of a round until that round has finished.

18. The device cannot contain any biological components. For example, you are not allowed to employ a trained squirrel as part of your device.

19. The ornaments to be used in the competition will be supplied by us. You cannot choose which ornament your team will retrieve or make any modifications to the ornament. You also cannot choose which lane your device will run in.

20. The ornaments we use are further described in Appendix B.

21. Electric motors. In the past a high percentage of devices have used electric motors. This is fine, but can run up the cost and weight of your device. We have tried deliberately to try to keep the cost of this competition as low as possible. We encourage teams to come up with elegant low-cost ways to meet the requirements that do not require motors. We have also obtained a supply of 6V DC motors with reduction gears. There is one of these motors available for any team that would like one. Appendix C provides the specs for these motors. They appear to weigh about 2 ounces.

22. In each round your team will have a maximum of 45 seconds for you to place your device onto the fixture and move away prior to the start. We will be loading the fixture with the teams having the inside lanes placing their devices first. Then the teams having the outside lanes will place their devices. You will have a maximum of 30 seconds to remove your device after the judges have declared the round over and allow the teams to move to the fixture.

23. Your team must check into the registration table at the designated time given in Appendix D. If your team is more than 5 minutes late, and this is deemed to hold up the competition, your team will lose its first round.

24. Damaging the fixture. Your team will be disqualified if your device intentionally or unintentionally damages the fixture in any manner including but not limited to: breaking any part of the fixture,

generating noticeable nixes or notches that will impact the integrity of the competition, adding foreign substances such as oil or lubricants onto the fixture.

25. Judging. The TAs (Amit and Nick) will determine which device accomplished which tasks during each round. They are also the primary referees to observe any safety violations. Device weights will be recorded at checkin and may be rechecked later if devices have been modified.

26. Protests. All protests must be registered immediately after the competing round. You must qualify your protests based on the ground rules and the project definition. Keep good engineering records (engineering book) of your development process to use to defend your positions. If you have no supporting documentation at the day of the competition, your protest will be disallowed. Bert Vermeulen will be the final judge on all protests.

27. And keep in mind. This competition is a lot of fun and an opportunity to cheer and encourage everyone. Feel free to invite your friends and family as well. You can see elements of the last four year's competitions at www.mech202.com.

28. Can we use a spring? There's no problem in using a spring, rubber band, or other means of propulsion as long as it does not generate so much force as to be dangerous. Using a crossbow, for example would be considered dangerous because we don't think any of your team members would feel safe standing in front of it.

29. Can we grab our device after it completes the task? Not until the round has been declared completed. Please ensure that your device cannot fall of the table, damage itself, or spin its wheels in a way that will damage the table or generate excessive heating.

30. Will there be any changes made to the competition fixture prior to April 27? We may make minor improvements to ensure that the fixture is stable and race worthy. These changes may slightly affect the geometry of the fixture and the starting gate, but not alter any of the fundamental functionality.

31. Note that, although we will do the best we can, we cannot guarantee that the fixture will be absolutely rigid. Please design your device to be as tolerant as possible of any movement that may occur to the fixture as it is used during the competition.

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

The Rewards
1. The winning team will receive an A for the course and will not have to take the final examination
2. The 2nd place team will receive an A for the project and a 100 for the final
3. The 3rd place team will receive an A for the project

Note that all three winning teams must be present during the lecture on April 30, as we may ask you to help explain to others in the class how you designed your device and some of its more successful features.

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

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

The Lead Up

Your design group may ask any questions whatsoever of Bob Thilmont, Bert Vermeulen or the TAs. This is strongly encouraged to ensure that your device meets the spirit of the competition. We encourage you to use RamCT to ask these questions. If you email questions to us, these questions and their answers will be posted on RAMCT. If you have any of us sign a “non-disclosure agreement” (sample attached), we will then discuss with you confidentially those issues you have, and will not disseminate your questions or the answers to the entire class.

Required Report
If you did not get one of the top three places in the competition, your grade for this project will be based almost entirely on the report that you submit, with the following clarifications:

A. Your competition outcomes will not affect the grade of the report unless you place in one of the top 3 positions.

B. We reserve the right to lower your grade for the project if we feel that you did not make a serious effort to build a device capable of meeting all of the tasks described in the competition objectives.

The report must be turned in as a correctly labeled single PDF (GroupXX_P2.pdf) with any supplemental materials in a zip file or folder that is also correctly labeled (GroupXX_P2.zip). These items must be turned into the drop folder on the T-Drive by 8am on Saturday, April 27. You cannot compete if we have not received the electronic copy of your report. You do not need to submit a paper copy.

The report will consist of:

Page 1 (Cover sheet) must be in the exact format shown in Appendix E and have the following information:

- Group number
- Names and email address for each member of your group
- Checklist of all report content and page(s) where this content can be found

Page 2 (Title page)

- A title identifying the device
- A photo of the device to fit in the remainder of the space on this page

Pages 3 and beyond of the report will have all of the other information required as listed below. Note that it is important that each section has page numbers that correspond to the pages listed on the cover sheet and that the first page of each section is labeled so that we can identify which section we are reading as we go through the report.

a. A project plan and documentation showing the relationship between actual completion of project tasks versus plan. This project plan is similar to what we requested for Project 1. In addition, we need an estimate of the number of hours spent by each team member on this project and the total number of hours spent by your group.

b. Documentation showing the process your group used to develop the specification for your device. You can use any methodology you would like for specification development, but your process should incorporate the steps you learned in the first half of this class. It should also be as clear and easy to follow as possible. Your specification development process should incorporate competition rules as well as other requirements your group decided were relevant for meeting your group's goals for the competition and report. The last step of this process is the specification you designed the device to meet. This specification should be in your own words, drawings, charts, equations, etc. Your specification should attempt to quantity as much as possible using measurements that can later be verified. Please include how you prioritized the musts and wants in your specification.

c. An engineering analysis of the specification developed in the previous step including an analysis of the physical and technical challenges the device needed to overcome. We expect you to demonstrate that you can use what you've learned in other subjects as part of the design process. This is an important section and has historically been significant in the report grades, and success in the competition.

d. A description of the alternative concepts your group considered and the process used to make the choices that lead to the design (or designs) your group decided to build and test as prototypes. The conclusion of this sections needs to tie back to the specifications and analysis performed in previous steps.

e. A set of drawings or photos that show how your device functions. These don't need to be CREO drawings and they don't need all details. There needs to be text to accompany the drawings/photos that explains in sufficient detail so that anyone "skilled in the art" (i.e. another student in this class) could buy the necessary components and fabricate a device that functioned similarly to your device.

f. A bill or materials that lists the cost of each item required to fabricate your device and where this item might be obtained. The bill of materials should be totaled so that we know how much it costs to build a device similar to yours. Also please tell us how much in total you spent (including spares, parts you didn't end up using, things that broke, etc)

g. A description of the testing that you did to verify that your device would perform well in the competition. This should include a description of things you learned during these tests and improvements that you made as a result of testing.

h. A safety analysis of your design or design choices showing risks and what your team did to minimize the most critical hazards.

i. A reliability and design margin analysis of your design or design choices showing the places where you believe your device is most likely to fail and what you have done to build design margin into those areas. This should also identify how much variability in the dimensions of the competition fixture your device can tolerate and an assessment of the impact of vibration during storage and usage that your device can tolerate.

j. A service and support plan for your device in case any part of your device should fail and you need to make emergency repairs during competition day.

k. A description of how your team worked together and what you learned about teamwork.

The grading of this report is done using the same approach as for Project 1, but we do not need CREO models and we expect significantly better technical analysis and grade to a higher standard based on the things that you've learned in this class. Just like for Project 1, we expect that reports worthy of a grade of 90 or above will demonstrate initiative by including additional relevant material, demonstrate critical thinking in the analysis, and have a "WOW" factor to them.

Post Mortem

By Monday evening April 29 (at 6pm), all groups including those that won first, second, or third place should turn in brief post-mortem listing five – ten things they learned from the competition. Doing a post-mortem is a good idea for any project. This will also be part of your grade for the project. More details of the content of the post-mortem will be provided prior to the due date.

APPENDIX A.

Request for Confidentiality (use if you need to share info with TAs or Instructors)

The undersigned agrees to hold confidential information of a competitive nature with the group members listed here. If the discussion leads to items of general interest (eg. – rules, competition or grading clarification), the design group allows publication of those items of general interest. Otherwise, any discussion of a competitive nature leading to a competitive advantage for the group will be held confidential.

Signed: Dated:

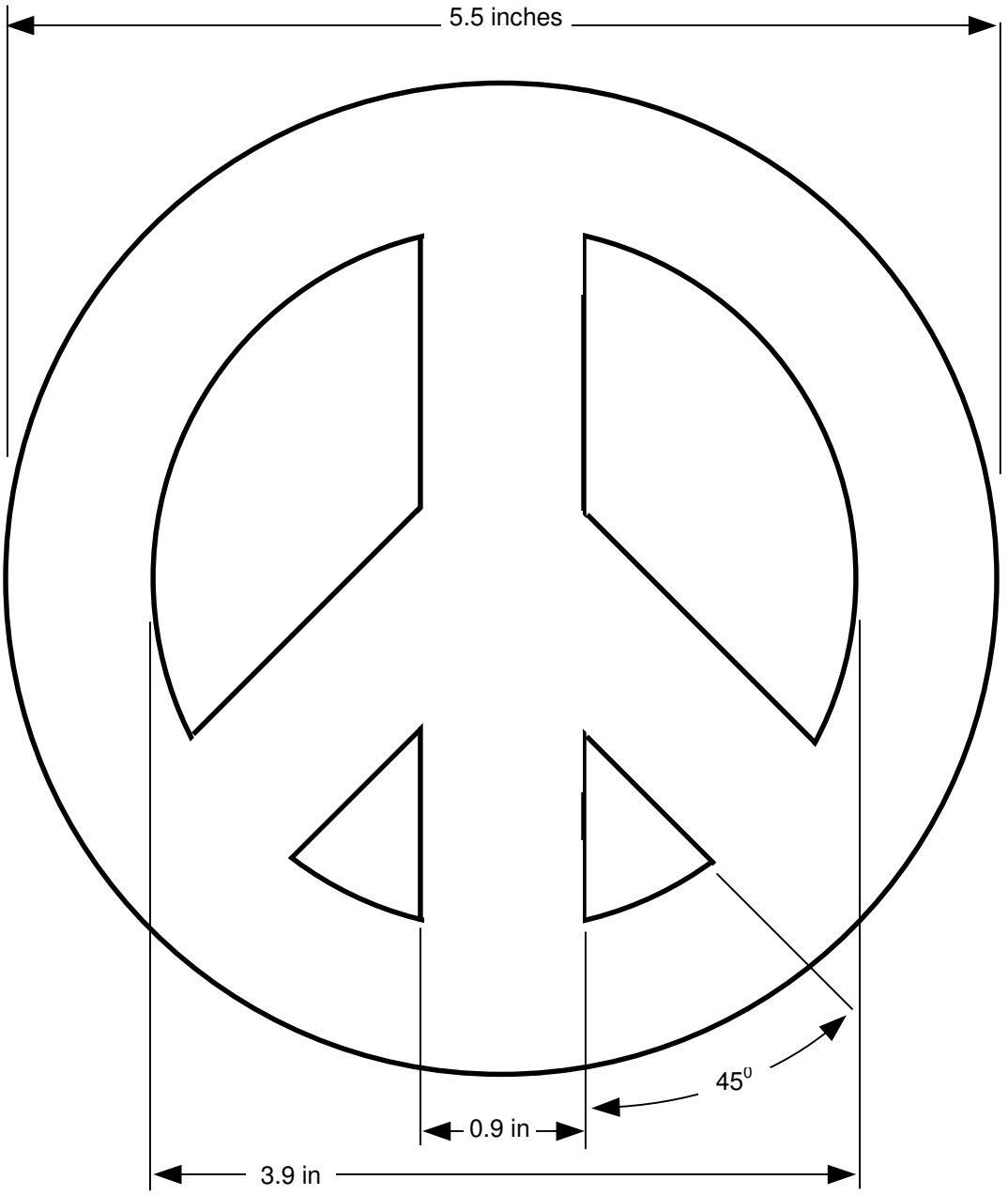
APPENDIX B. Fixture Parts List, Ornament Dimensions, and Supplementary Sketches

1. **Ping pong table.** We are using a regulation ping-pong table that is standard width and height and has a standard surface on it. The one we are using was purchased at Sports Authority and was a pretty basic model costing less than $200. We have propped one end up vertically.

2. The **lumber to make the starting locations** the main pieces are 2x4s (which means they measure approximately 1.5x3.5 inches in cross section. Each starting location is approximately 12 inches wide by 12 inches deep. The height is the height of the 2x4, or approximate 3.5 inches.

3. The **hook** is a 10-32 threaded rod. This means the outside diameter is approximately 0.2 inches.

4. The following is a sketch of the ornament. It is approximately 0.070 inch (1/16") thick and weighs almost nothing. It is made of foam.

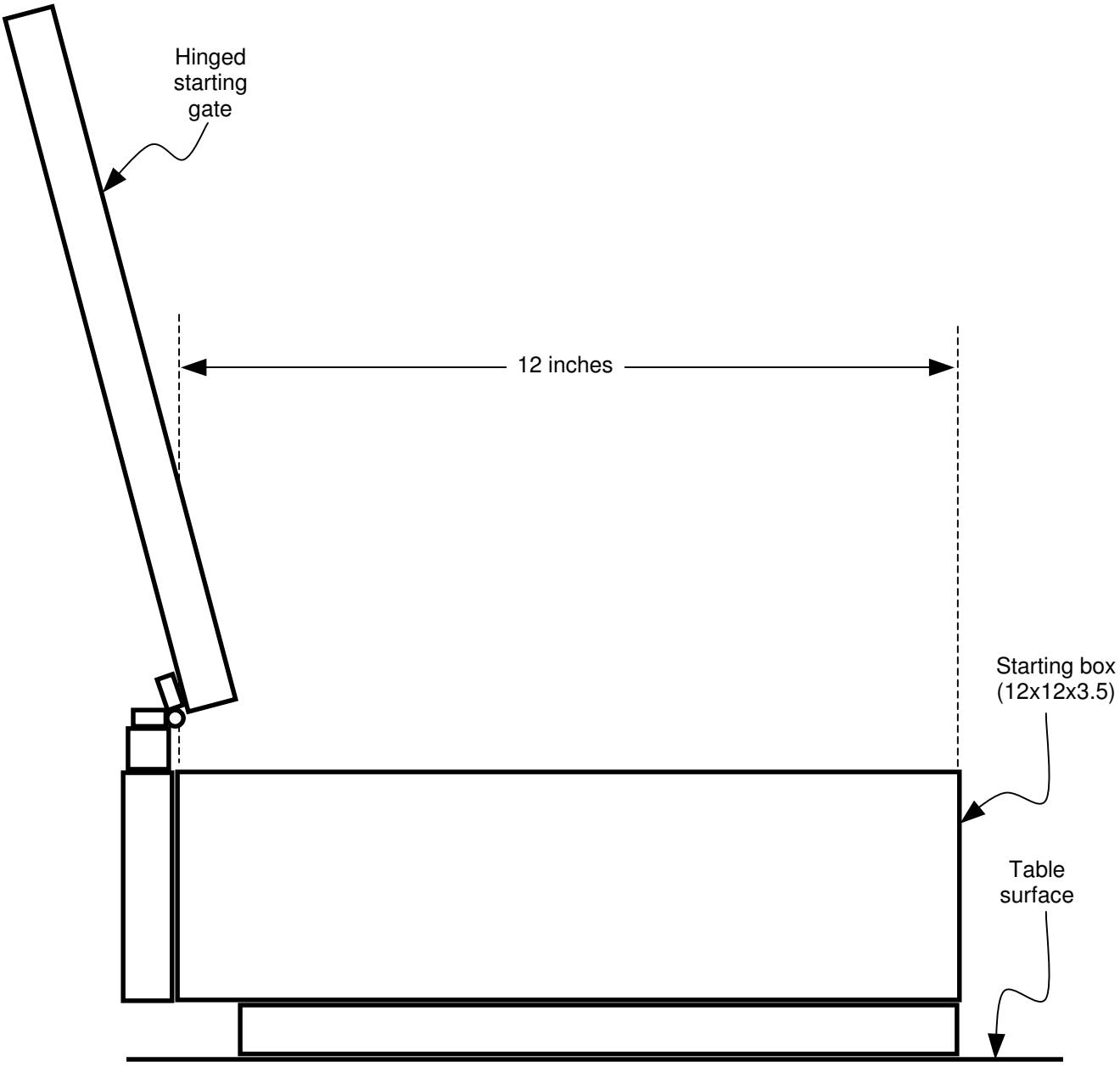


5. Below is a sketch of the side view of the starting locations with the starting gate opened. Note that the location of the starting gate interferes slightly with the 12" vertical projection of the box. However, ince the starting gate has opened the vertical "lane" for your device includes the region 12" in front of your box as described previously. We encourage you to make your device as tolerant as possible of variations in the fixture.

6. Each **hook** is approximately centered over the center of each 12x12 box and approximately 44 inches above the table surface.

7. We also encourage you to **make your device as tolerant as possible of vibration of the fixture** during competition.

8. Your device **is allowed to touch the hook** in the region vertically above your 12" wide x 24" deep vertical lane.



APPENDIX C. Electric Motors

An anonymous donor has contributed small DC motors to the Mechanical Engineering department for use on student projects. We have enough motors to give each team one motor that they can use for their second project. The motors operate at 6V and include a reduction gear that provides a speed of about 90 RPM at 6V no load.

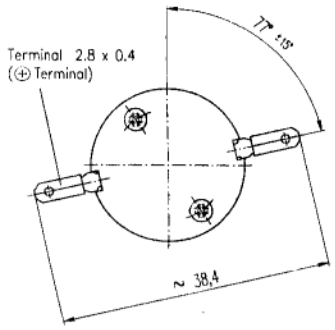
Each team is entitled to 1 motor. If you burn it out, there's no spare and the motors themselves are pretty pricey to buy.

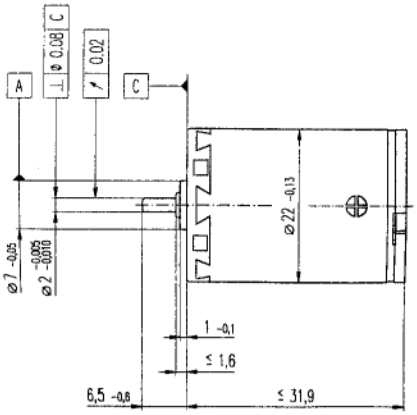
We don't necessarily recommend that you use an electric motor for your second project. You'll need to do your analysis to determine whether to use an electric motor and whether this would be the motor that you want to use. Remember that the heavier your device, the more the bungee will sag. We haven't weighed them, but the motors appear to be about 2 ounces. If you decide to use one of these motors, please include your engineering analysis of why you chose to use this motor.

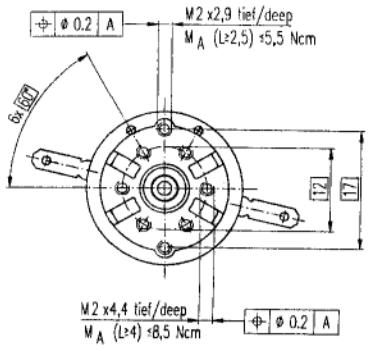
The motors can be picked up in the TAs office.

The next two pages provide the specs on the motor. It is a Maxon 110117. The reduction gear appears to be a spur gear. Based on measurements made, we believe the spur gear is either providing a 64:1 or a 131:1 reduction.

A-max 22 ∅22 mm, Precious Metal Brushes CLL, 5 Watt, CE approved







M 1:1

Stock program
Standard program
Special program (on request)

Order Number	110117	110119	110120

Motor Data				
	Values at nominal voltage			
1	Nominal voltage	V	6.0	
2	No load speed	rpm	9640	
3	No load current	mA	29.6	
4	Nominal speed	rpm	7480	
5	Nominal torque (max. continuous torque)	mNm	4.81	
6	Nominal current (max. continuous current)	A	0.840	
7	Stall torque	mNm	21.5	
8	*Starting current*	A	3.65	
9	*Max. efficiency*	%	83	
	Characteristics			
10	Terminal resistance	Ω	1.64	
11	Terminal inductance	mH	0.106	
12	Torque constant	mNm / A	5.90	
13	Speed constant	rpm / V	1620	
14	Speed / torque gradient	rpm / mNm	452	
15	Mechanical time constant	ms	19.1	
16	Rotor inertia	gcm²	4.04	

Specifications

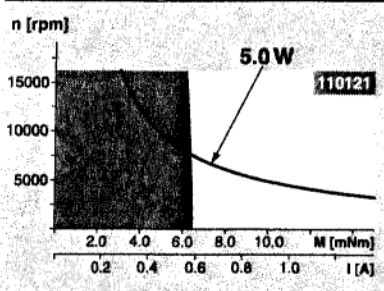
	Thermal data	
17	Thermal resistance housing-ambient	20 K / W
18	Thermal resistance winding-housing	6.0 K / W
19	Thermal time constant winding	10.1 s
20	Thermal time constant motor	540 s
21	*Ambient temperature*	-30 ... +65°C
22	*Max. permissible winding temperature*	+85°C
	Mechanical data (sleeve bearings)	
23	Max. permissible speed	16000 rpm
24	Axial play	0.05 - 0.15 mm
25	Radial play	0.012 mm
26	Max. axial load (dynamic)	1 N
27	Max. force for press fits (static)	80 N
28	Max. radial loading, 5 mm from flange	2.8 N
	Mechanical data (ball bearing)	
23	Max. permissible speed	16000 rpm
24	Axial play	0.05 - 0.15 mm
25	Radial play	0.025 mm
26	Max. axial load (dynamic)	3.3 N
27	Max. force for press fits (static)	45 N
28	Max. radial loading, 5 mm from flange	12.3 N
	Other specifications	
29	Number of pole pairs	1
30	Number of commutator segments	9
31	Weight of motor	54 g

CLL = Capacitor Long Life

Values listed in the table are nominal.
Explanation of the figures on page 49.

Option
Ball bearings in place of sleeve bearings
Pigtails in place of terminals
Without CLL

Operating Range



Comments

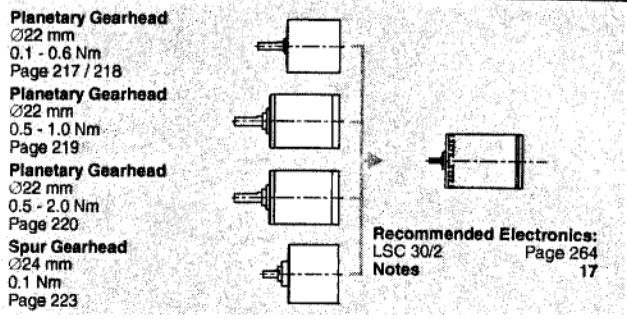
Continuous operation
In observation of above listed thermal resistance (lines 17 and 18) the maximum permissible winding temperature will be reached during continuous operation at 25°C ambient.
= Thermal limit.

Short term operation
The motor may be briefly overloaded (recurring).

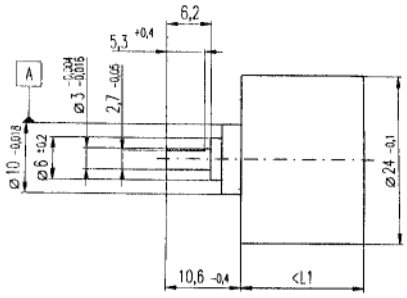
Assigned power rating

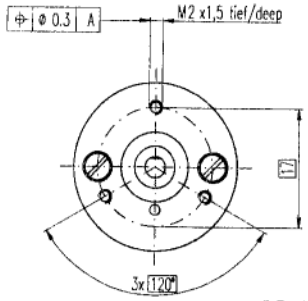
maxon Modular System

Overview on page 17 - 21



Spur Gearhead GS 24 ∅24 mm, 0.1 Nm





M 1:1

Technical Data

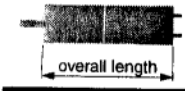
Spur Gearhead	straight teeth
Housing	plastic
Output shaft	stainless steel, hardened
Bearing at output	sleeve bearing
Radial play, 8 mm from flange	max. 0.038 mm
Axial play	0.03 - 0.30 mm
Max. radial load, 8 mm from flange	5 N
Max. permissible axial load	8 N
Max. permissible force for press fits	500 N
Average backlash no load	< 2.5°
Recommended input speed	< 4000 rpm
Recommended temperature range	-20 ... +100°C
Extended area as option	-35 ... +100°C

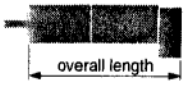
maxon gear

Stock program
Standard program
Special program (on request)

Gearhead Data		Order Number 110480	110481	110482	110483	110484	110485	110486
1 Reduction		7.2 : 1	20 : 1	32 : 1	64 : 1	131 : 1	199 : 1	325 : 1
2 Reduction absolute		93/13	121915/6153	151613/4656	837/13	212629/1625	778642/3909	1093365/3362
3 Max. motor shaft diameter	mm	2	2	2	2	2	2	2
4 Number of stages		2	4	4	4	4	6	6
5 Max. continuous torque	Nm	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6 Intermittently permissible torque at gear output	Nm	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7 Sense of rotation, drive to output		=	=	=	=	=	=	=
8 Max. efficiency	%	81	66	66	66	66	53	53
9 Weight	g	25	28	28	28	28	30	30
10 Average backlash no load	°	1.0	2.0	2.0	2.0	2.0	3.0	3.0
11 Mass inertia	gcm²	0.008	0.01	0.008	0.007	0.006	0.008	0.006
12 Gearhead length L1*	mm	13.7	17.4	17.4	17.4	17.4	21.2	21.2

*for A-max 19 is L1 + 2.8 mm



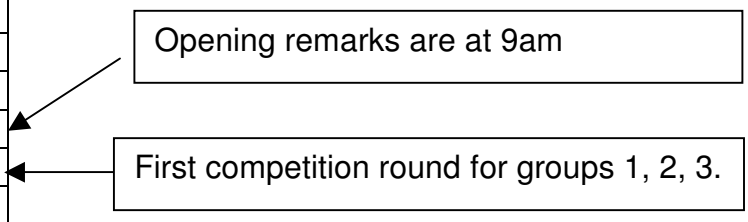


Combination

+ Motor	Page	+ Tacho / Brake	Page	Overall length [mm] = Motor length + gearhead length + (tacho / brake) + assembly parts						
A-max 19	105/106			45.5	49.2	49.2	49.2	49.2	53.0	53.0
A-max 19, 1.5 W	106	MR	243/244	50.6	54.3	54.3	54.3	54.3	58.1	58.1
A-max 19, 1.5 W	106	Enc 22	249	59.9	63.6	63.6	63.6	63.6	67.4	67.4
A-max 19, 1.5 W	106	MEnc 13	258	53.0	56.7	56.7	56.7	56.7	60.5	60.5
A-max 19	107/108			48.1	51.8	51.8	51.8	51.8	55.6	55.6
A-max 19, 2.5 W	108	MR	243/244	52.4	56.1	56.1	56.1	56.1	59.9	59.9
A-max 19, 2.5 W	108	Enc 22	249	62.5	66.2	66.2	66.2	66.2	70.0	70.0
A-max 19, 2.5 W	108	MEnc 13	258	55.6	59.3	59.3	59.3	59.3	63.1	63.1
A-max 22	109-112			45.7	49.4	49.4	49.4	49.4	53.2	53.2
A-max 22	110/112	MR	243/244	50.7	54.4	54.4	54.4	54.4	58.2	58.2
A-max 22	110/112	Enc 22	249	60.1	63.8	63.8	63.8	63.8	67.6	67.6
A-max 22	110/112	MEnc 13	258	52.8	56.5	56.5	56.5	56.5	60.3	60.3

APPENDIX D. REGISTRATION TIMES ON APRIL 27

Registration Time	Groups
8:15 am	1, 2, 3
8:19 am	4, 5, 6
8:23 am	7, 8, 9
8:28 am	10, 11, 12, 13
8:32 am	14, 15, 16
8:36 am	17, 18, 19
8:40 am	20, 21, 22
8:45 am	23, 24, 25, 26
8:50 am	27, 28, 29
8:54 am	30, 31, 32
8:58 am	33, 34, 35
9:02 am	36, 37, 38, 39
9:07 am	40, 41, 42
9:11 am	43, 44, 45
9:15 am	46, 47, 48
9:19 am	49, 50, 51, 52



Note: Each team must check into the registration table at the designated time given above. Any team that is more than 5 minutes late runs the risk of losing its first round.

Appendix E
Cover Sheet Template

Group Number ____

Group Members	Email Addresses

Section	Pages where found
Cover sheet	1
Title and photo of device	2
Project plan & hours spent	
Specification development	
Engineering analysis	
Concept development and choice	
Illustrated description of device function	
Bill of materials	
Description of testing	
Safety analysis	
Reliability and design margin analysis	
Service and support plan	
Teamwork analysis	

Supplemental Information	Where located