530.216 Mechanics Based Design Laboratory
Design Project, Spring 2024

1. Objective
   1.1. The objective of this project is to design and construct a crane capable of lifting a known weight off of the floor by a specified distance and within a specified time limit.

2. Design teams
   2.1. Cranes will be designed and constructed by teams of two or three students.
   2.2. All members of a design team must be in the same lab section.
   2.3. Each team must choose a professional-sounding and “sellable” company name (i.e. a name that would convince a potential customer that you are a serious design company). For example, “JLC Designs” is a good name. “Prestige Worldwide” is not a good name. “Team Crane” is not a good name, either (too boring). Names that reference the surname of your instructor are not permitted.
   2.4. Each team must email Dr. Marra a list of their members and team name by February 13.

3. Location of crane and weight
   3.1. Each crane will be tested in the Wyman Park Building, room 163.
   3.2. Crane mounting plate
      3.2.1. A 8.25” × 8.25” × 0.5” aluminum plate will be clamped to the corner of a work table. (see Figures 1 and 2).
      3.2.2. The plate will contain twenty-five (25) ¼-20 tapped holes located at 1.5” centers (see Figure 2). Cranes must be mounted directly to the plate.
      3.2.3. The top of the mounting plate will be approximately 36 inches above the ground.
   3.3. Weight
      3.3.1. The weight will be ten (10) pounds.
      3.3.2. The weight will be resting on the floor below the table top at the start of each evaluation.
      3.3.3. The center of the weight will be located (horizontally) eighteen (18) inches from the front edge of the crane mounting plate (see Figure 1).
      3.3.4. The weight will include a hanger and hook, from which it may be lifted. The hook will be located approximately 22 inches below the top surface of the mounting plate.
      3.3.5. The weight must be raised vertically straight up (it cannot be dragged along the floor).

4. Lifting distance and time limit
   4.1. The ten-pound weight must be raised one (1) inch above the floor.
   4.2. The weight must be reach a height of one (1) inch above its starting position within two (2) minutes.
   4.3. A prize will be awarded to the team that can lift the weight to a height of one (1) inch in the shortest amount of time.

5. DC gearmotor assembly
   5.1. Each team will be provided with one micro gearmotor (Sparkfun part number ROB-12125, www.sparkfun.com/products/12125). This is the only motor that may be used for this project.
   5.2. A six (6) volt power supply will be used to power the gearmotor during crane testing. No other power source may be used during the evaluation.
   5.3. The stall torque of the gearmotor is rated at 12 oz-in at 6 volts input.
   5.4. The maximum speed of the gearmotor is 140 RPM.
   5.5. The gearmotor assembly includes a mounting plate and coupler for a ∅ 0.25” shaft.
   5.6. Major dimensions of the gearmotor assembly are provided in Figure 3.
   5.7. The replacement of a damaged gearmotor will cost $12.95 and must be paid in advance before a new gearmotor will be provided.
   5.8. Photographs of the gearmotor assembly are provided in Figure 4.
   5.9. Each team is responsible for returning their gearmotor assembly, undamaged, at the end of the project. A 10% final project grade reduction will be imposed for all team members if these parts are not returned.
   5.10. Counterweights may not be used.

6. Horizontal boom
   6.1. The boom for each crane must be oriented horizontally (i.e. parallel with the floor).
   6.2. The boom must be constructed primarily from a plastic material (e.g. acrylic, PVC, nylon).
   6.3. The boom may not be constructed from PVC pipe.
   6.4. The boom may not be constructed from fiberglass.
   6.5. The (downward) deflection of the end of the boom will be monitored during the crane evaluation.
   6.6. The (downward) deflection of the end of the boom must not exceed 0.5 inch when lifting the ten (10) pound weight.
   6.7. Support cables may not be used.

7. Restrictions on style of crane

   7.1. Lever-based crane designs are not permitted.

   7.2. No parts of the crane may be welded together.

8. Materials and parts supplied

   8.1. The following items will be provided for use by all teams during the crane evaluations:

      8.1.1. Crane mounting plate

      8.1.2. Six (6) volt power supply

   8.2. The following materials and parts will be provided directly to each team. Teams will not be charged for using these items unless replacements are required.

      8.2.1. One (1) gearmotor assembly

      8.2.2. One (1) 7.75” x 7.75” x ¼” sheet of acrylic

         8.2.2.1. Note that a ¼” thick sheet of acrylic has tolerances of +0.020" and -0.040"

         8.2.2.2. Any additional acrylic must be purchased by the design team (see section 9)

         8.2.2.3. Scrap acrylic may be used for prototyping and testing ideas, but it must not be hoarded, and any acrylic used in the crane beyond what was obtained from the 7.75” x 7.75” x ¼” sheet must be included in the cost analysis.

      8.2.3. Teams will be given two different cables, each eight (8) feet in length.

         8.2.3.1. Nylon-coated stainless steel wire rope, 0.037" diameter, 20 lb load capacity, McMaster-Carr part number 8930T26

         8.2.3.2. Clear nylon line, 0.022" diameter, 30 lb breaking strength, McMaster-Carr part number 9442T3

   8.3. Additional materials and parts provided

      8.3.1. The yellow bins near the red tool box in Wyman 163 contain various fasteners and other small parts which are available to students for this project. Use of these items is on a first-come basis. **Hoarding of items is not permitted.** All items taken from these bins must be included in the final cost analysis, with a well-estimated price assigned to each (see section 16.3.6.2). Items that are taken and not used must be returned.

      8.3.2. Screws (and nuts) of various lengths and sizes, including ¼-20 screws for fastening your crane to the mounting plate, will be made available to you for free and should not be included in your cost estimate.

9. Additional materials and parts
    - 9.1. Each team will be permitted to purchase up to $25 worth of additional parts (e.g. gears, pulleys, shafts, collars, bearings, other materials) for their design.
    - 9.2. Parts may only be obtained from McMaster-Carr. Parts may not be obtained from any other source.
    - 9.3. If parts can only be purchased in large quantities (e.g. parts sold in packs or in lengths significantly longer than needed), teams will only be charged for what they use. However, **no group may order more than $40 worth of parts.**
    - 9.4. Wood may not be used for any part of the crane.
    - 9.5. **Adhesives may only be used with the permission of Dr. Marra.**
    - 9.6. Ordering process
        - 9.6.1. Part order requests are to be submitted using a Google form which will be available to you after Spring Break.
        - 9.6.2. Dr. Marra may refuse to order parts for any reason.

10. Work area
    - 10.1. Design teams will be given J-card access to Wyman 163 after Spring Break.
    - 10.2. **The room must be kept clean and functional.**
    - 10.3. The development and running of the scheduled MBD labs takes precedence over any project work in the room.
    - 10.4. No student is permitted to work in room 163 alone. There must be at least two people in the room at all times (unless the room is empty).
    - 10.5. Each team will be given a bin in which to store their parts and materials. Bins must be placed neatly out of the way of traffic when they are not being used.

11. Fabrication and assembly
    11.1. Design teams may use the mill, lathe, and the drill presses in Wyman 163 to cut parts.
        11.1.1. The mill and lathe are only to be used for cutting plastics.
        11.1.2. Cutting tools (end mills, drill bits) must be returned to their proper place when not in use.
        11.1.3. **The work areas must be kept neat and clean at all times.**
    11.2. A variety of basic hand tools (Allen wrenches, screw drivers, pliers, wrenches, hacksaws, etc.) will be available for use in Wyman 163. These tools are not to leave the room and must be returned to their proper place when finished.
    11.3. Parts may not be fabricated using a 3D printer/rapid-prototyping machine.
    11.4. Students who have been officially trained to use the laser cutters and the equipment in the WSE student machine shop may do so for this project.

12. Drawings

12.1. Drawings must be created for all parts requiring laser cutting or machining.

12.1.1. Each part must be presented on a separate drawing.

12.1.2. All drawings must include the following information:

- Title (i.e. part name)
- Units
- Scale
- Material
- Quantity required
- Team name
- Team members' last names
- Date
- Drawing number
- Revision number

12.1.3. Drawings must be properly dimensioned according to the ANSI standard.

12.1.4. Drawings must be in units of inches.

12.1.5. Proper orthographic projections must be used if needed to convey the correct information about a part.

12.1.6. Values of the pitch, number of teeth, and pressure angle must be included on all drawings of gears.

12.1.7. An example part drawing is provided in the Appendix.

12.2. An assembly drawing of the crane must be submitted.

12.2.1. **All parts**, including those purchased, must be indicated on the assembly drawing.

12.2.2. A parts list ("Bill of Materials") must be included in the upper right corner of the assembly drawing with the following information for each part:

- Part name
- Part drawing number, or "N/A" if the part has been purchased
- Number of parts in the assembly

12.2.3. An example assembly drawing is provided in the Appendix.

12.2.4. SolidWorks part and assembly files for the gearmotor subassembly are available for your use on Canvas.

12.3. **All drawings in the final design report must be done in CAD.**

12.4. A SolidWorks drawing template (Sheet Format file) is available for download from Canvas. Any drawing created in SolidWorks must use this template.

13. Design notebook

13.1. A design notebook is not a requirement of this project, but the use of a notebook is strongly encouraged.

13.2. Individuals who submit a *proper* design notebook with their team's project report may earn up to five (5) extra credit points for the project, depending on the quality of the notebook.

14. Design meetings with Dr. Marra

14.1. Each team is required to meet with Dr. Marra at least twice during the semester to review their designs.

14.2. All team members must be present during both official meetings.

14.3. First official meeting

14.3.1. The first official design meeting will occur during the regularly scheduled lab section times during the week of February 26.

14.3.2. Each team is expected to arrive to this meeting with their solutions to the problem set located in the Appendix. Solutions should be written neatly and clearly, and presented on a separate sheet of paper (or multiple sheets) to be handed in to Dr. Marra. Points will be deducted for incorrect answers.

14.3.3. Each team is expected to arrive to this meeting with three lists regarding the project specification:

14.3.3.1. List of items (things, actions, etc.) that the crane must have or must do (e.g. The crane must raise the 10-pound weight by one inch).

14.3.3.2. List of items that the crane must not have and must not do (e.g. Support cables must not be used).

14.3.3.3. List of specifications that limit your decision making processes (e.g. Parts may only be obtained from McMaster-Carr).

14.3.4. Each team is expected to arrive to this meeting with presentation-quality **hand** sketches (i.e. sketches that you would not be embarrassed to present to a group of professional mechanical engineers) of their proposed approach for the crane boom. **CAD drawings are not acceptable.**

The sketches should show the length and cross-section of the boom and the method of securing it to the mounting plate. Information on possible materials, estimated dimensions, and methods for manufacturing the boom should also be included. **All values should be supported by calculations.**

14.3.5. Each team is expected to arrive to this meeting with a set of presentation-quality **hand** sketches of their proposed approach for the crane transmission system. **CAD drawings are not acceptable.**

The transmission sketches should also include values of the important parameters (e.g. gear ratios, number of pulleys, number of bearings). **All values should be supported by calculations.**

14.4. Second official meeting

14.4.1. The second official design meeting will occur during the regularly scheduled lab section times during the week of April 1.

14.4.2. Each team is expected to arrive to this meeting with a full assembly drawing of their crane and detailed engineering drawings of all parts to be fabricated. **Drawings for this second meeting must be done in CAD, and must meet the requirements given in section 12.**

14.4.3. Each team is expected to arrive to this meeting with a complete list of the assumptions made during the design of their crane.

14.4.4. Each team is expected to arrive to this meeting with the following calculations for their proposed crane:

- Expected maximum boom deflection
- Expected maximum boom bending stress
- Estimated stresses at any significant stress concentrations
- Motor torque required to lift the weight

Explanations must be provided for all design factors used in the calculations (see *Design Factors, Safety Factors, and Factors of Safety* document).

14.5. Unofficial meetings with Dr. Marra throughout the semester are welcome and encouraged.

15. Design evaluation

15.1. Cranes will be evaluated during the last week of classes during the regularly scheduled lab sections.

15.2. Cranes will be evaluated based on the following criteria:

15.2.1. Was the crane able to raise the ten-pound weight by one inch?

15.2.2. Was the crane able to raise the weight the required distance in under two minutes?

15.2.3. Was the boom end deflection less than 0.5 inch?

15.2.4. What was the quality of workmanship in the manufacturing and assembling of the crane?

15.2.5. Did the crane perform as designed, or were there unexpected behaviors (e.g. lateral deflections)?

15.2.6. Was the crane damaged during the evaluation?

15.2.7. Did the crane include any unauthorized parts and/or materials?

16. Design report

16.1. Each team must submit a (single) design report by 5pm on the last day of the semester.

16.1.1. A no-penalty extension of three days will be granted provided that room 163 and the laser cutter room are kept neat and clean throughout the semester. Any complaint from a member of the Whiting School or Wyman Housekeeping regarding the condition of either of these rooms will result in the canceling of this extension.

16.2. Design reports should be printed electronically, except for calculations which may be done by hand.

16.3. The design report should contain the following sections, with **separate headings for each**, in order:

16.3.1. A brief (less than one page) description of the final crane design, including:

16.3.1.1. Power transmission and lifting system

16.3.1.2. Boom and structural support system

16.3.2. Engineering CAD drawings, including assembly and individual parts, according to the specifications given in section 12.

16.3.3. Explanations and justifications of structural design factors used in calculations.

16.3.4. Explanations and justifications of power transmission design factors used in calculations.

16.3.5. Design calculations

16.3.5.1. All mechanical calculations made in the design of the crane must be included in the report. These include:

16.3.5.1.1. Calculations of loading (e.g. forces, torques, stresses) and deformation (e.g. displacements, deflections, twists, strains) for all members under significant mechanical loads to ensure that failure (e.g. yielding, fatigue, excessive deformation) will not occur.

16.3.5.1.1.1. A gear tooth bending stress analysis (ala Lewis) is required for any design that includes gears.

16.3.5.1.1.2. A belt stretch analysis is required for any design that includes belts.

16.3.5.1.2. Calculations related to the power transmission and lifting system, including the expected torque/RPM of the gearmotor during lifting of the weight.

16.3.5.2. Calculations must be presented in a clear and concise manner that is easy to follow and understand.

16.3.5.3. Each calculation should be presented on a separate page (or multiple pages, if necessary).

16.3.5.4. The top of each calculation page should include the following information:

- Descriptor of calculation
- Team name
- Team members' last names
- Page number and total number of pages for the calculation

16.3.5.5. Each calculation should include the following information:

- Knowns
- Information to be determined from the calculation
- Design factor used, if relevant.
- Assumptions
- Identification of significant equations used

16.3.5.6. References must be included for all material property values.

16.3.5.7. Calculations may be written by hand, but they must be neat and legible.

16.3.5.8. A calculation page template is available for download from Canvas.

16.3.5.9. An example calculation page is provided in the Appendix.

16.3.6. Cost analysis, including:

16.3.6.1. Total cost of the crane, excluding gearmotor assembly, 7.75" x 7.75" x ¼" sheet of acrylic, and any screws/nuts provided to you.

16.3.6.2. A breakdown of the individual cost of all crane components, excluding those listed above, including an explanation as to how the individual cost was calculated if necessary.

16.3.7. A one-page summary of the performance evaluation results, including:

16.3.7.1. The expected amount of boom end deflection based on the design calculations.

16.3.7.2. The actual amount of boom end deflection.

16.3.7.3. A description of the crane performance, including what did and did not work as expected, with explanations as to why.

16.3.8. A one-page sheet detailing the contributions of each team member

16.3.8.1. What did each member individually contribute to the design and fabrication of your crane, and to the project report?

16.3.8.2. What parts of the project did you work on together as a group?

16.3.9. A one-page sheet entitled “Growth, Improvements, and Advice” containing the following:

16.3.9.1. A list of five (5) things (knowledge and/or skills) the team learned during the project that can be applied to future design work (example: “1. We learned that acrylic is a very brittle plastic and care must be taken when machining it.”)

16.3.9.2. A list of three (3) suggestions for improving the crane design based on the performance evaluation.

16.3.9.3. A list of three (3) suggestions for improving the design project assignment.

16.3.9.4. One piece of advice for next year’s MBD Lab students to help them design and construct a successful crane (assume the project specifications will not change)

17. Grading

17.1. The design report will count for 40% of the design project grade. The report will be scored as follows:

17.1.1. Overall content and presentation of report – 20%

17.1.2. Sound justifications and reasoning for design decisions – 15%

17.1.3. Quality of drawings – 15%

17.1.4. Quality of calculations – 15%

17.1.5. Cost analysis – 5%

17.1.6. Performance evaluation summary – 15%

17.1.7. Growth, Improvements, and Advice – 15%

17.2. The final, scheduled, performance evaluation will count for 20% of the design project grade.

17.3. <u>Each</u> of the official meetings with Dr. Marra will count for 20% of the design project grade.

17.4. **All teams must produce a crane that meets all of the design requirements in order to pass this course.**

17.4.1. **If a team is unable to produce a satisfactory crane during their final performance evaluation, then they will have until the last day of the final examination period to do so.**

17.4.2. **If they are still unable to produce a satisfactory crane by this date, then all members of the team will receive a failing grade for the course.**

18. Tentative schedule

2024 MBD Lab Project Calendar

Monday	Tuesday	Wednesday	Thursday	Friday
29 Start of MBD Lab 1	30 Design project assigned	31	1	2
5 Start of MBD Lab 2	6	7	8	9
12 Start of MBD Lab 3	13 **Team members and team names due (email Dr. Marra)**	14	15	16
19 Start of MBD Lab 4	20	21	22	23
26 Start of MBD Lab 5 **First project team meetings during lab**	27	28	29	1
4 Start of MBD Lab 6	5	6	7	8
11	12	13	14	15
18 Spring Break	**19 Spring Break**	**20 Spring Break**	**21 Spring Break**	**22 Spring Break**
25	26	27	28	29
1 Start of MBD Lab 7 **Second project team meetings during lab**	2	3	4	5
8 Start of MBD Lab 8	9	10	11	12
15	16	17	18	19
22 **Final evaluations (during MBD Lab)**	23 **Final evaluations (during MBD Lab)**	24 **Final evaluations (during MBD Lab)**	25 **Final evaluations (during MBD Lab)**	26 **Project reports due**

Advice from last years' students

- Our advice for next year's MBD Lab students is to make use of the collaborative work environment in the lab. As a small group you can only try so many ideas and designs, so learning from what other groups are trying as well can be invaluable to improving your design process and your final design.
- If your group is stuck on something, talk to other groups - if you're struggling with something there's probably a chance another group is dealing with that same issue too.
- It is important to keep in mind that the laser cutting room and machine shop become very crowded at the end of the semester due to projects from other courses.
- Communicating well leads to better ideation and prototyping. Many times, design choices were made from building off one another's ideas. To do so, working in the same space helped improve communication and productivity. We were able to discuss the design often and make changes together. With everyone having the same, clear vision for the design, members could work efficiently to complete tasks and encourage one another when there was an issue.
- Learn how to properly use the arbor press if you are going to make press fits, and don't underestimate the precision needed for quality press fits.
- Set up unofficial meetings with Professor Marra to go over any doubts or receive confirmation about design ideas. This will only help with ensuring that the final product works as expected.
- One piece of advice would be to expect low efficiency and start early so you have time to make big changes if necessary. Particularly with the gears, we underestimated how precise the gear spacing had to be and regardless of how well positioned they were, they did not have a high efficiency.
- The simpler you can make your design, the better. Everything takes longer and is a little bit more difficult to manufacture and operate than expected.
- Expect your first design to not work. Remember that the design process is iterative and plan to spend time improving or reworking your idea.
- Try not to design the whole thing in one day, as you will get stuck in that design and have to keep making modifications throughout fabrication to accommodate for flaws in that design. Start with high-level ideation and take the time to work through the advantages and disadvantages each idea provides.
- Prototype and test early. Do not be afraid to use scrap material available to test concepts because it is rare that your first design will work as expected or that you will not want to make any revisions to your initial design. It is best to figure these things out ASAP.
- Do not overthink the design in any aspect of the project. This project is meant more to demonstrate your use of MBD principles than a creative design, so a straightforward design that is well-calculated will be your best bet.
- A recommendation for future MBD Lab students is to start simple and build up from there, and give yourself time to manufacture everything.
- Our advice for the students next year is to be precise with your planning and dimensioning because it makes machining much easier.

Advice from previous years' students

- Start the project as soon as possible!
- Assume you will run into problems so start early.
- Make sure to order your parts and start manufacturing as early as possible. If you run into issues with your design and/or parts being delayed, you want time to adjust and correct and issues.
- Keeping documentation of every meeting that your team has will save a lot of time when writing the final report. It also makes it easier for members to catch up on what they missed if they cannot make it to a meeting.
- Be extremely organized with your work. Dedicate a notebook solely to this project.
- Keep your design simple and ask yourselves if there is a simpler way to meet the requirements. There is less
- Make sure that you allot enough time to preparing before you start machining, like taking accurate measurements.
- Take into account the listed tolerances in the dimensions of parts ordered from McMaster-Carr. While these values are typically small, they can cause interference in the fit between parts if you do not design to accommodate them.
- Do not overcomplicate the design - a simple design is the easiest path to success.
- Minimize the number of complicated moving parts in the crane, as the quality of workmanship and material will have a large impact on the friction in the lifting mechanism.
- Start machining early since you will likely run into manufacturing challenges, and give yourself time to make changes to your design as you test.
- Manufacturing mistakes are going to happen, so be patient and maintain a steady workflow.
- Weekly team meetings are a must. Even if you only have 20 min to spare, spare them! It will help your team work cohesively through a good relationship between one another and will keep you all on schedule. You'll be able to find obstacles together and solve them together.
- Physically working in the same location as your group mates for all aspects of the project makes a significant impact on the communication and team dynamic. Yes, you may want to split up the work sometimes (ex: someone doing CAD while another does stress concentration calculations). However, being in the same location allows you to constantly ask questions of each other and ensure every aspect of the project has been a collaborative effort.
- Make sure to set aside time each week to meet and incrementally work on the project. It will make preparing for the meetings for Dr. Marra easier and help at the end of the semester when things get hectic.
- Start as early as you can because you never know if you need last-minute orders or if you need to replace some of your resources, or if you need to change the material you are using for the crane.
- One thing we learned was the importance of alignment. Although we knew the shafts had to be properly aligned, we did not think about how the applied forces would cause everything to deform.

- It would have been extremely helpful if our lab design group had kept a design notebook to keep track of all changes made to our design. There were several occasions in which a change was made to the design while one of our group members was not present. Keeping a design notebook with all changes made to the design would have kept the entire group up to date on the most recent changes to the design.
- Another thing the team learned throughout the project was the significance of alignment in designs. A few times during the process of constructing and machining we encounter multiple problems and difficulties due to slight misalignments. While some of these mishaps were the result of machining error, a few were due to applied forces causing parts to deform, and thus, not align properly.
- Start the entire process as early as possible. Problems will arise such as machines breaking. In addition, it can be helpful to practice on scrap materials before constructing final design.
- Do not overthink the design of your project and keep it simple!
- It is important to take into account that the materials you order from websites might not be the exact size they are advertised as and to account for uncertainties like this. The beam that we ordered was actually considerably smaller than its advertised 0.5" width, instead being about 0.45" in width.
- One piece of advice for next year's MBD Lab students would be to keep things simple. Sticking with a simple design reduces the probability of error occurring, thus increasing your chances of making a successful device.
- We cannot emphasize enough the importance of fully planning out your design before you implement it. Even with extensive planning, we encountered several situations in the construction of the assembly that we failed to account for.
- To next year's MBD class, I would suggest that they come up with a design with as little friction as possible because that proved to be the biggest issue in our design.
- Meet with your design team early and schedule extra meetings with Dr. Marra to make sure your design will work. It is a lot of work and very stressful if you leave it until the weekend before.
- Get started on the manufacturing process as early as possible. You will most likely run into issues and the earlier you catch them the better. Also, towards the due date the lab gets very crowded, so the earlier you finish, the less you'll be waiting for machines and testing apparatuses.
- Next year's students should be aware that the laser cutter will break down and they should start constructing their device early. The earlier the students start the project, the less people they will have to share tools with. This will ultimately cut down on the amount of time spent in Wyman because there will be close to no wait time to use the machines.
- When working on group projects it is hard to find times when everyone can meet. Therefore when time is found, it is important to use it efficiently. Communication plays a big part of time management such as when to meet and what the plan is. This was vital during the MBD design project because we all had two other projects due the same week.
- If we were to offer up one piece of advice for next year's MBD lab students, it would be to start early. Not just because the design process takes a long time, but also so that the inevitable mistakes and unforeseen challenges are discovered when there is still time to fix them.

- Future students embarking in the odyssey of designing and building the crane should start early and keep a detailed design notebook. The notebook is helpful toward the end while writing the report.
- While building the crane, students should be *very* meticulous and detail oriented when cutting pieces. Students should always take a step back and visualize the final product before actually making a cut.
- Consider the manufacturing process when designing. It is simple enough to come up with an idea, and maybe you can even make it in CAD, but can you make it a reality?
- Because there is only one laser cutter and one of most other machines, we learned that it was important to schedule a lot of time to get things done as many students had to use the equipment at the same time and wait times on most of them were quite long.
- As far as advice, we very much recommend having not only drawings of each individual part, but also a detailed assembly drawing before beginning any machining. This is very helpful when you are fabricating and assembling as it makes the process run smoother.
- It would have been helpful to have made a step-by-step list of what needed to be done and in what order. A few times during the process we found ourselves asking "what's next?". Having a list would've allowed us to finish one part of the design and immediately been able to move on to another pre-planned portion of the project.

19. Appendix

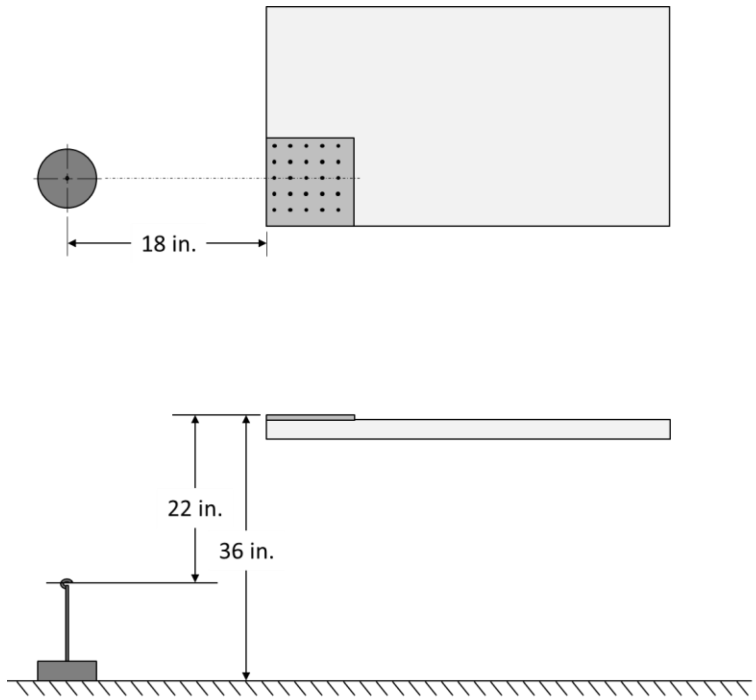


Figure 1 – Top and side views of table top, crane mounting plate, and weight.

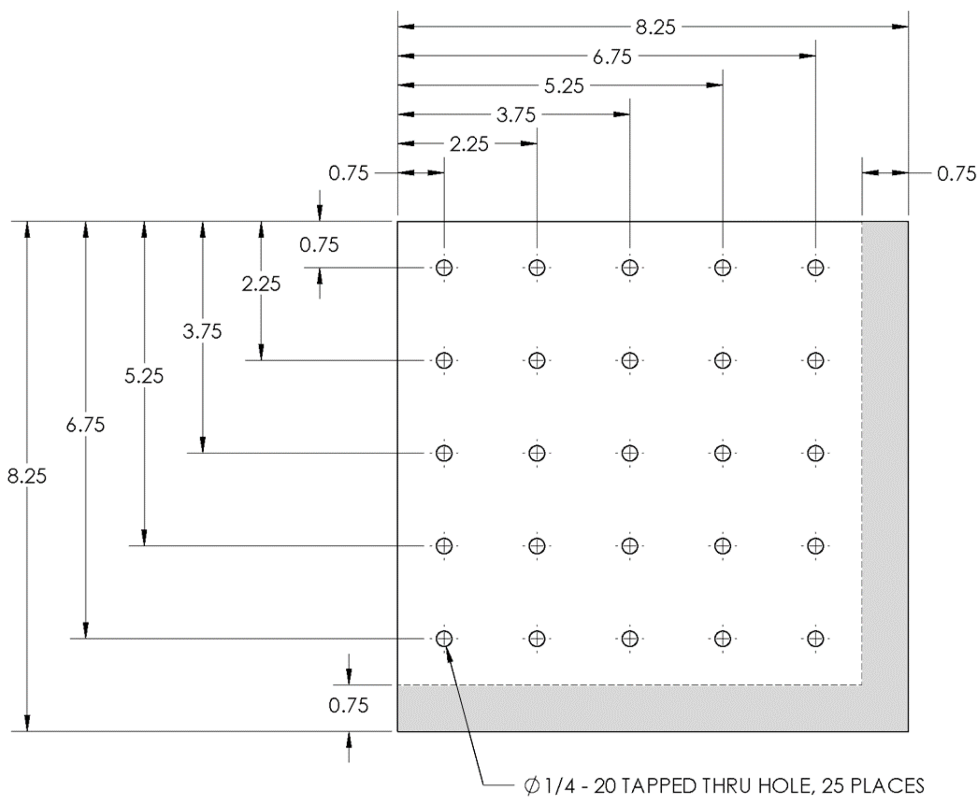


Figure 2 - Dimensions (in inches) of crane mounting plate. Cranes may be mounted to the plate using any of the 1/4-20 threaded holes. The plate is 0.5" thick.

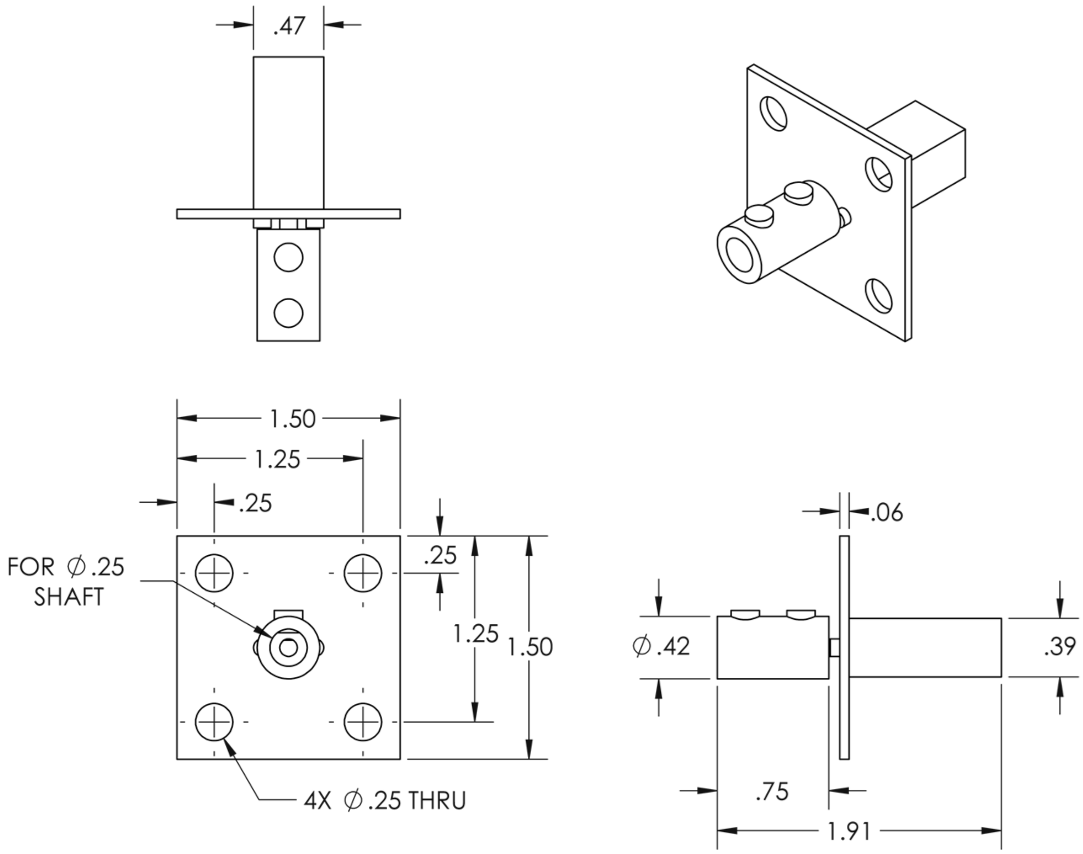


Figure 3 – Major dimensions (in inches) of gearmotor assembly

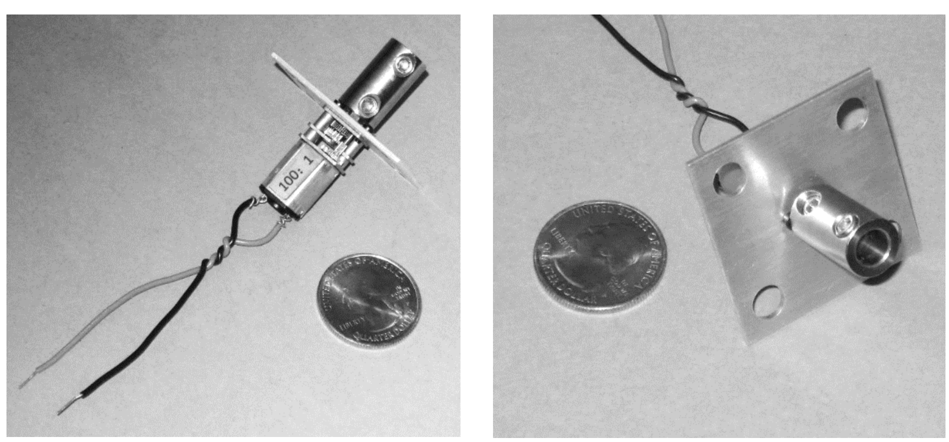
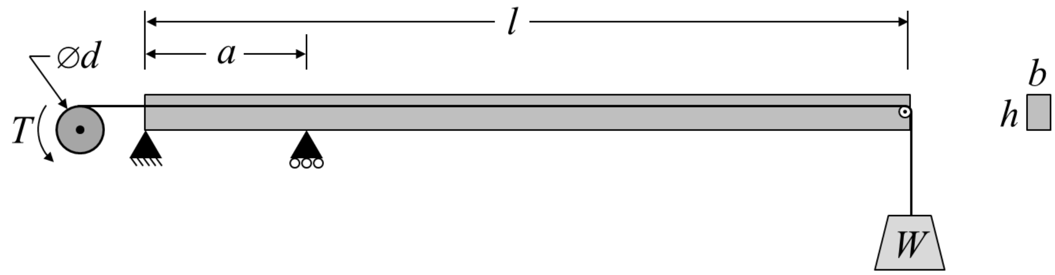


Figure 4 – Photographs of the gearmotor assembly.

Problem Set for First Official Meeting with Dr. Marra

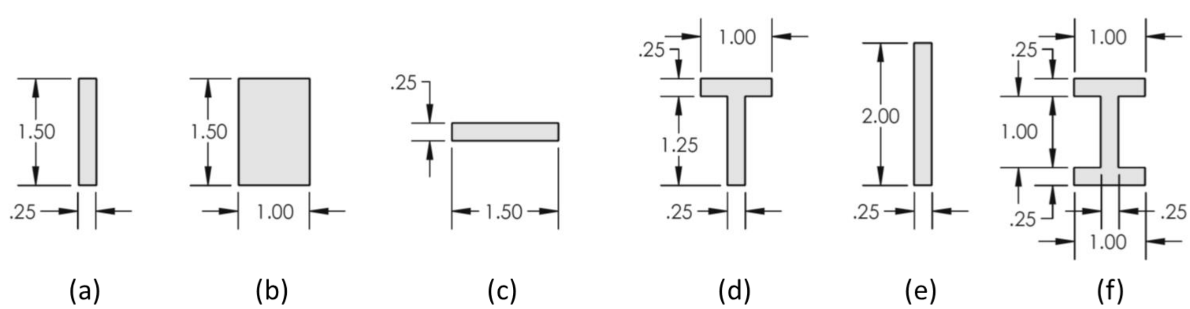


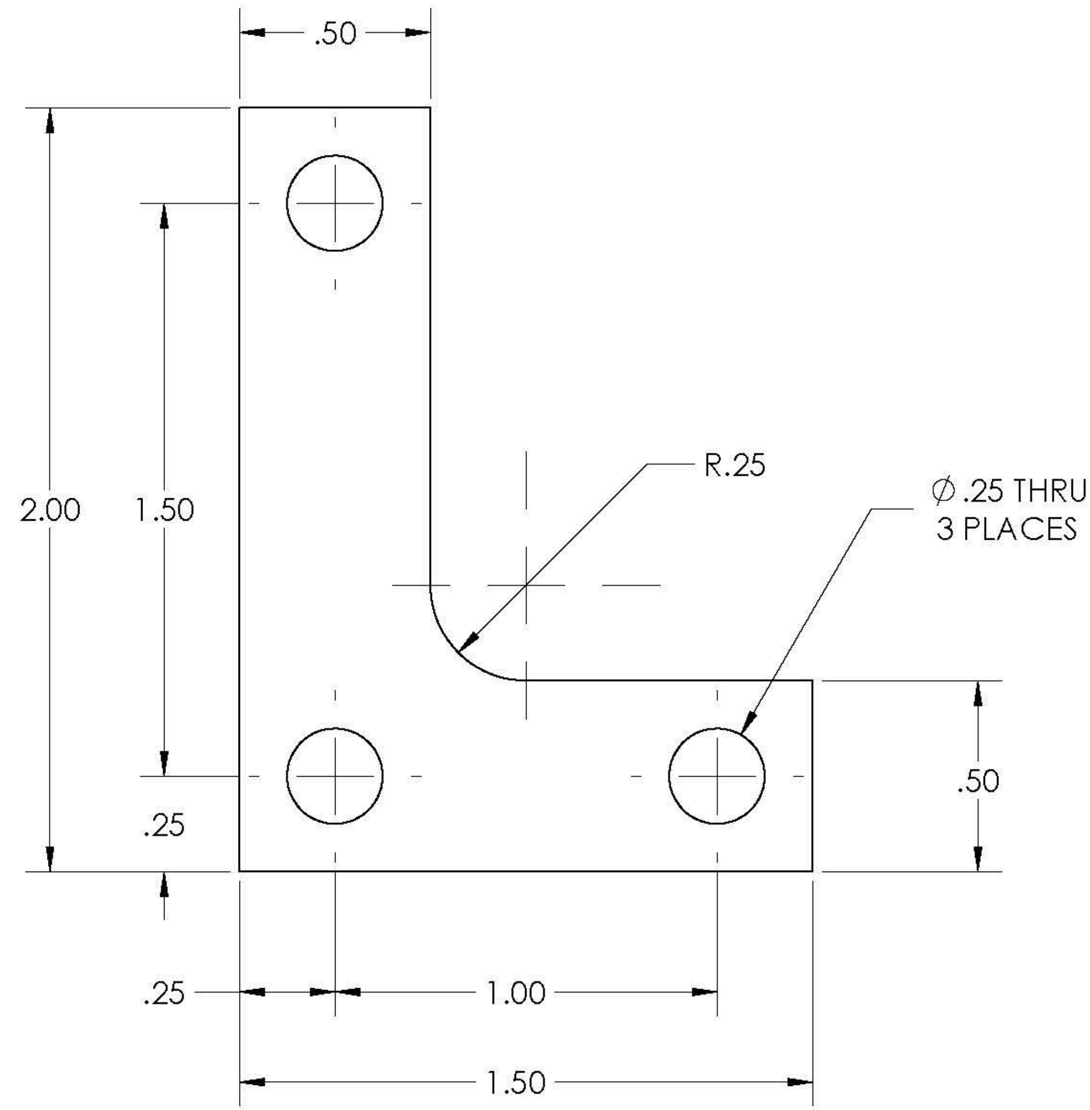
A horizontal beam of length l, height h, and width b is supported by two pin connections. One pin connection is located at the far-left end of the beam and the other pin connection is located a distance a from the far-left end of the beam. The beam is made from a material with a Young's modulus of E.

An object of weight W hangs from the right end of the beam via an inextensible cord. The cord follows a path vertically upward from the weight, then around a (frictionless) pulley at the right end of the beam, then horizontally past the left end of the beam to a spool around which it is wound.

The spool has an outer diameter of d.

1. Is the beam a cantilever (according to Shigley)? (Hint: see tables at end of textbook)
2. What is the maximum tensile stress in the beam and where (horizontally and vertically) is it located?
3. What is the deflection of the right end of the beam?
4 There is an applied horizontal compressive force acting on the beam (in addition to the applied downward force acting at the free end of the beam). What is this force?
5. How much torque, T, must be applied to the spool to raise the object?
6. For a beam of length l that is mounted and loaded as shown above, rank the six (6) cross-sections shown below based on how much the right end of the beam would deflect (from least amount of deflection to most deflection). Show your work.

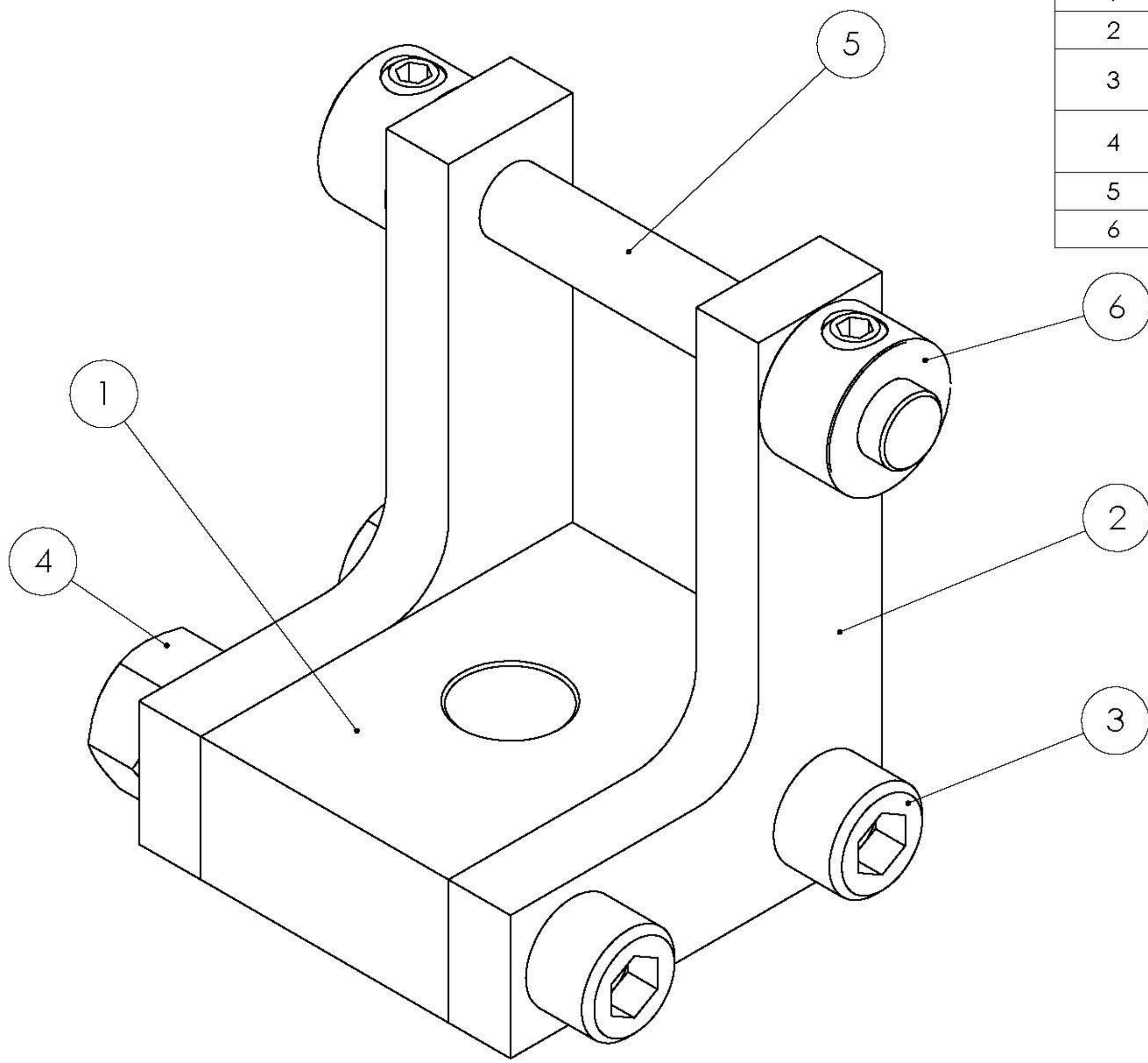




530.216 MBD LAB	TITLE: L-BRACKET		UNITS: INCHES	SCALE: 2:1	MATERIAL: 1/4" THICK ACRYLIC		QTY. REQ.: 2
	TEAM: STUGE DESIGNS	DRAWN BY: LARRY FINE			DATE: 22JAN24	DWG. NO.: 12-3	REV. NO.: 1

5 4 3 2 1

ITEM NO.	PART	DRAWING NUMBER	QTY.
1	BASE PLATE	12-1	1
2	L-BRACKET	12-3	2
3	1/4-20 X 1.75 SOCKET CAP SCREW	N/A	2
4	1/4-20 NUT	N/A	2
5	1/4 DIA SHAFT	12-2	1
6	1/4 SHAFT COLLAR	N/A	2



530.216 MBD LAB	TITLE BRACKET ASSEMBLY	UNITS INCHES	SCALE 2:1	MATERIAL	QTY. REQ. 1
	TEAM STUGE DESIGNS	DRAWN BY MOE HOWARD	DATE 5FEB24	DWG. NO. 12-4	REV. NO.

5 4 3 2 1

Knowns: P = 10 lb
b = 0.5 in
h = 0.5 in
L = 18 in

Design factor = 2

Find: Maximum bending stress

Assumptions: Boom acts as a cantilevered beam

Solution:

$$\sigma_{max} = (DF)(M_{max})(h/2) \;/\; I$$

$$M_{max} = P\,L$$

$$I = b\,h^3 / 12$$

So,

$$\sigma_{max} = (2)(PL)(h/2) / (b\,h^3 / 12)$$

$$= (2)(10\times18)(0.5/2) / (0.5 \times 0.5^3 / 12)$$

$$= (2)(10\times18)(0.5/2) / (0.5 \times 0.5^3 / 12)$$

$$= \boxed{17.3 \text{ kpsi}}$$