Design Contest
ME72 Engineering Design Laboratory
Fall Term, 2001
Syllabus
(Revised: October 23, 2001)

Professor: Erik Antonsson
Office: 323 Thomas
erik@design.caltech.edu

12 Units (3-8-1)
3 hours class: Tue 10:00 am, Thur 10:00 am, Thur 2:00 pm, 306 Thomas
8 hours lab/shop
1 hour home work

Final Contest: 2:00 pm, Thursday December 6th, 2001, Beckman Auditorium

http://www.design.caltech.edu/Courses/ME72/
Syllabus, week by week:

1. 2-Oct, Tue  Brief Class Meeting. Handouts. The Design Process.  
   Objectives, Requirements, Specifications, Constraints and Functions.  
4-Oct, Thur  Models of the Design Process,  
   Discussion of Objectives, Requirements, Specifications, Constraints and Functions.  
4-Oct, Thur  M.E. Shop: Introduction to the shop. Shop use and safety.  
   Introduction to the Design Contest.  
2. 9-Oct, Tue  Methods for Generating and Evaluating Design Alternatives:  
   Brainstorming, Delphi Method, Method 635.  
   Structured Methods of Pahl and Beitz.  
11-Oct, Thur  Team Building.  
11-Oct, Thur  Introduction to Motors and Power Transmissions, Impedance Matching.  
   Belt/Pulley Drives.  
3. 16-Oct, Tue  Motors and Power Transmissions, continued  
   16-Oct, Tue 7:00 pm Preliminary Design Reviews (PDR’s).  
   17-Oct, Wed 7:00 pm Preliminary Design Reviews (PDR’s).  
   18-Oct, Thur  Preliminary Design Review Summary.  
   Mechanical Interfaces, # Connection Constraints. String Drives  
   18-Oct, Thur  In-class demonstrations: Silicone, Gear alignment, Soldering.  
4. 23-Oct, Tue  Bearings and Shafts.  
   Helical, Worm and Bevel Gears. Epicyclic Gear Trains.  
   Couplings, Hooke’s and CV-Joints, Clutches and Brakes.  
25-Oct, Thur  M.E. Shop: Key Element Prototype Due.  
5. 30-Oct, Tue  Pugh Charts, QFD, Introduction to Taguchi Methods.  
   Discussion of Devices from Previous Years.  
1-Nov, Thur  Quality, FMEA. Quality Philosophy (Robert Pirsig).  
1-Nov, Thur  Design in Industry.  
6. 6-Nov, Tue  Mechanical Properties of Engineering Materials  
   6-Nov, Tue 7:00 pm Critical Design Reviews (CDR’s).  
   7-Nov, Wed 7:00 pm Critical Design Reviews (CDR’s).  
   8-Nov, Thur  Critical Design Review Summary.  
   Brainstorming applied to the Contest Device.  
8-Nov, Thur  M.E. Shop: Key Operation Test.  
7. 13-Nov, Tue  
   15-Nov, Thur  
   15-Nov, Thur  M.E. Shop: Device Prototype Due.  
8. 20-Nov, Tue  Contest Discussion.  
   22-Nov, Thur  Thanksgiving Vacation, No Class.  
9. 27-Nov, Tue  
   29-Nov, Thur  Contest Discussion/Preparation.  
   29-Nov, Thur  M.E. Shop: Device Function Test.
10. **4-Dec, Tue**  Beckman Auditorium: Preliminary Contest.
    **6-Dec, Thur**  Beckman Auditorium: Device Size and Weight Test.
    **6-Dec, Thur 2:00 pm**  Beckman Auditorium: Final Contest.
- Contest Device Schedule and Milestones:

<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Day</th>
<th>Time</th>
<th>Milestone</th>
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<tbody>
<tr>
<td>1</td>
<td>2-Oct</td>
<td>Tue</td>
<td>10:00 am</td>
<td>Zeroth Assignment given.</td>
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<td>4-Oct</td>
<td>Thur</td>
<td>10:00 am</td>
<td>Objectives, Requirements and Functions Assignment;</td>
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<td>3 Alternatives Assignment;</td>
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<td>Mockup Assignment given.</td>
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<td>2</td>
<td>9-Oct</td>
<td>Tue</td>
<td>10:00 am</td>
<td>Zeroth Assignment Due.</td>
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<td>Objectives, Requirements and Functions Due [5%].</td>
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<td>3</td>
<td>16-Oct</td>
<td>Tue</td>
<td>10:00 am</td>
<td>Engineering Analysis Assignment given.</td>
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<td></td>
<td>16-Oct</td>
<td>Tue</td>
<td>7:00 pm</td>
<td>Preliminary Design Review.</td>
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<td>17-Oct</td>
<td>Wed</td>
<td>7:00 pm</td>
<td>Preliminary Design Review.</td>
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<td>3 Design Alternatives Due [5%].</td>
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<td>Mockups Due [5%].</td>
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<td>Begin building Prototypes of key elements.</td>
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<td>Begin Fabrication of Device.</td>
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<tr>
<td>4</td>
<td>23-Oct</td>
<td>Tue</td>
<td>10:00 am</td>
<td>Engineering Analysis Assignment Due [5%].</td>
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<td></td>
<td>25-Oct</td>
<td>Thur</td>
<td>2:00 pm</td>
<td>Prototype of 1 key (working) element Due [5%].</td>
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<td>5</td>
<td>1-Nov</td>
<td>Thur</td>
<td>2:00 pm</td>
<td>Continue Fabrication.</td>
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<td>Begin Testing and De-Bugging.</td>
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<td>6</td>
<td>6-Nov</td>
<td>Tue</td>
<td>7:00 pm</td>
<td>Critical Design Review.</td>
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<td></td>
<td>7-Nov</td>
<td>Wed</td>
<td>7:00 pm</td>
<td>Critical Design Review.</td>
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<tr>
<td></td>
<td>8-Nov</td>
<td>Thur</td>
<td>2:00 pm</td>
<td>Demonstration of 1 key function. Due [5%].</td>
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<td>7</td>
<td>15-Nov</td>
<td>Thur</td>
<td>2:00 pm</td>
<td>First Complete Device Prototype Due [5%].</td>
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<td>First version fabrication complete.</td>
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<td>Continue Refinement.</td>
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<td>8</td>
<td>21-Nov</td>
<td>Wed</td>
<td>5:00 pm</td>
<td>Devices Impounded for Thanksgiving Break.</td>
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<tr>
<td>9</td>
<td>26-Nov</td>
<td>Mon</td>
<td>8:00 am</td>
<td>Impounded Devices Returned.</td>
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<td>29-Nov</td>
<td>Thur</td>
<td>2:00 pm</td>
<td>Device Scoring Function Test [5%].</td>
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<td></td>
<td>Size and Weight Test.</td>
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<td>Continue Refinement.</td>
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<tr>
<td>10</td>
<td>4-Dec</td>
<td>Tue</td>
<td>10:00 am</td>
<td>Preliminary Contest: Beckman Auditorium.</td>
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<td>44 Second Set-up Time Test.</td>
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<td></td>
<td>6-Dec</td>
<td>Thur</td>
<td>10:00 am</td>
<td>Device Size and Weight Test: Beckman Auditorium.</td>
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<td>Devices Considered Complete.</td>
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<td>Device Construction to Cease.</td>
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<tr>
<td>11</td>
<td>6-Dec</td>
<td>Thur</td>
<td>1:30 pm</td>
<td>Contestants Assemble in Beckman Auditorium.</td>
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<td>6-Dec</td>
<td>Thur</td>
<td>2:00 pm</td>
<td>Final Contest: Beckman Auditorium.</td>
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<tr>
<td>12</td>
<td>11-Dec</td>
<td>Tue</td>
<td>5:00 pm</td>
<td>Contest Evaluations Due.</td>
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<td></td>
<td>13-Dec</td>
<td>Thur</td>
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<td>Device Grading. [40%]</td>
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Office Hours:
If there is sufficient interest, I will maintain office hours for questions and consultations. Hours to be arranged. The Teaching Assistants and I will also hold “shop hours”, hours when they will be available in the shop to answer questions and provide advice. Hours to be arranged.

Shop Hours:
The M.E. Shop will be open from 8:00 am to 5:00 pm Monday through Friday. The Shop will be open during the lunch hour. The Shop will be closed to ME72 students during ME72 class times.

Shop Machine Sign-ups:
The M.E. Shop staff have instituted a sign-up procedure to schedule time on the lathes and mills in advance. Please refer to the sign-up sheets in the entry-way to the shop for rules and details.

Design Reviews:
We will hold two design reviews during the term. One on Tue 16-Oct and Wed 17-Oct, and one on Tue 6-Nov and Wed 7-Nov. On these days the time period beginning at 7:00 pm will be divided up into 20 minute (or so) time slots, one per team, to meet with the instructors. These meetings are an opportunity for the instructors to provide guidance and advice to the student teams on the progress of their designs. These meetings are not intended to be the only opportunities to meet with the instructors, but rather to ensure that a minimum of two meetings occur between each student and the instructors. (Other meetings can be arranged as needed or desired.)

Each student should be sure to bring his or her design notebook to the design review.

Each student will be asked to describe the status, operation, and plans of his or her teammate’s device.

Additionally, at the first review, the student should bring his or her 3-Alternatives assignment and Mockup. At the second review, the student should bring his or her device (or as much of it as is completed).

Device Photographs:
During the term, at the various milestones and design reviews, you will be asked to show the instructors your design notebook and any hardware that you have fabricated. At those times we will take photographs of your evolving device. This will serve as a record of the status of your design for grading purposes. The photographs will not be released to public view until after the contest is over. After December 6th, 2001, the photographs will be put on the ME72 Web page as part of an archive of the class activities.
• Teams

You will be required to work and compete in teams of two.

The class will be divided into two groups at the beginning of the term. You will be asked to rank 5 people, not in your group, in order of preference as your potential teammate. Teammates will be assigned based on these preferences, where possible, randomly if necessary.

Each student will be given a bag of junk from which to construct a device that will perform some part of the task outlined in the rules for this year’s design contest. It is up to you and your teammate to decide on the functions for your devices, subject to the constraints outlined in the rules. Keep in mind that the majority of your grade is based on the design and fabrication of your individual device. In other words, your device must be independently designed and built, though it must function in collaboration with your teammate.

• Collaboration Policy:

While you will be working in teams of two, it is expected that each individual will design and fabricate a functional device.

It is acknowledged that interaction between teams in the class is highly beneficial. To that end, any conversations, calculations, analyses, ideas and tests may be shared among the teams, but the device design and fabrication must be an individual effort. Note that this collaboration policy does not extend to replicating others’ ideas. Occasionally two people will arrive at a very similar solution independently, sometimes one person will see a great idea in someone else’s device, and finding no superior alternative will want to incorporate it. This duplication is permissible, however, not encouraged. Competitors usually maintain a high level of secrecy around their device, and blindly copying an idea or strategy may be risky.

In many respects, you should treat this design project as similar to an ordinary homework set. It is permissible to collaborate with your classmates and seek the advice of the instructor, TA’s, M.E. Shop staff, other class participants, other students, however, the final product must be your own work.

At the end of the term, for grading purposes, you must be able to indicate the boundary of the functional device that you designed and fabricated, and in particular to distinguish it from the device that your teammate designed and fabricated.

Additionally, it is vital to acknowledge the contributions of others to your ideas, by a suitable notation in your design notebook. If you are concerned about the acceptable limits to collaboration, discuss the situation with the instructor(s).

Do your own work, and as always, it is best if you use your own ideas and concepts.
Textbooks:

**Strongly Recommended Textbook:**

Shigley, Joseph E., and Charles R. Mischke,
*Mechanical Engineering Design*,
5th edition, McGraw-Hill, 1989,
($105.00)

**Strongly Recommended Textbook:**

Magrab, Edward B.,
CRC Press, 1997,
($65.00)

**Recommended Textbook:**

Pahl, Gerhard, and Wolfgang Beitz,
*Engineering Design: A Systematic Approach*,
Second Edition. Springer-Verlag, 1996,
($53.95)

**Recommended Textbook:**

Ulrich, Karl T., and Steven D. Eppinger,
*Product Design and Development*,
($86.65)

**Recommended Textbook:**

McKim, Robert H.,
*Thinking Visually: A Strategy Manual for Problem Solving*,
Dale Seymour Publications, 1997,
($18.95)
• Design Notebook:

You will be expected to keep a design notebook. This will be a place for you to record your thoughts and design ideas, (both in words and sketches) as well as a notebook for keeping track to things to do, and things accomplished. We want to see your design ideas as they unfold, in sketches and words, and notes and sketches concerning problems and improvements during testing. It is also crucial that you include notes on discussions with your teammate about your design concepts and alternatives, design strategies, compromises made, task divisions, refinements and improvements. Additionally, it is vital to acknowledge the contributions of others to your ideas, by a suitable notation in your design notebook.

The notebook itself can be anything you wish, a conventional $8\frac{1}{2}$ by 11 notebook, a large format drawing pad, a 100 foot roll of shelf paper, etc.

We will want to see the notebook weekly. We will collect them in the Thursday morning class, and return them in the Thursday afternoon class. If you wish to discuss your notebook, or your design, there will be time during the Thursday afternoon class, or during our office hours.

• Record of Hours Spent:

We also want you to keep track of your time, design time, fabrication time, and test/tune/refine/debug time. The best would be to record your time, as you work. It would be best if you also summarized this information into the number of hours you worked each week in the following format:

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<thead>
<tr>
<th>Week</th>
<th>Class</th>
<th>Design</th>
<th>Fabrication</th>
<th>Debug</th>
<th>Total</th>
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Remember that this is (now) a 12 unit course, which means that you should put 12 hours per week into it. This is a total of 120 hours for the term. You should also keep this number in mind as you apportion time to design, fabrication, testing/tuning/refining/debugging.

We will also ask for a summary of the number of hours you spent on the course, at the end of the term.
Grading

5% Objectives, Requirements and Functions (5% Individual)

5% Three Design Alternatives (5% Team)

5% Mockup (5% Individual)

5% Engineering Analysis Calculations (5% Individual)

5% Prototype of 1 Key Working Element (5% Individual)
   By this due date, one key element of one design must be built as a prototype for testing.

5% Prototype of 1 Key Function (5% Individual)
   By this due date, one key operating contest function must be built and its operation demonstrated.

5% Device Fabrication Complete (5% Individual)
   By this due date, the first version of your design must be completely fabricated.

5% Device Scoring Function Test (3% Individual, 2% Team)
   By this due date, your device must demonstrate legal compliance with all the contest rules, and must satisfy the minimum performance to successfully compete.

40% Contest Device:

10% Overall Concept (5% Individual, 5% Team)
   This is the overall idea of solving the design problem: e.g., wheels or tractor or airplane or catapult, string-drive or belts, etc. The team component is based on evidence (in the notebooks and devices) of team discussions and conceptualization (throughout the term) and on division of functions, mass, volume, etc.

10% Details (10% Individual)
   This category is for evaluation of the details of the design: e.g. how are the joints and fasteners designed, how are the bearing mountings designed, etc.

10% Execution (10% Individual)
   The grade for execution primarily relates to fabrication. How you implemented the concept(s) and details you designed: e.g., did you learn how to drill a straight hole, turn a diameter, and mill a flat surface, or does your device look as if it was whittled out with a pen-knife, etc.

10% Planning (5% Individual, 5% Team)
   In addition to meeting the milestones (above), this category evaluates your ability to have planned ahead, especially with regard to leaving enough time to build and test, modify and tune your design, as well as practice using it. Sketches and notes in your design notebook, along with the design reviews and other meetings with the instructors, are the only way that your planning can be evaluated. If you don’t show the instructor(s) what you are doing during the term, he will have to guess at your planning, a process that usually results in a low grade.
   Team planning is evaluated based on evidence in the notebooks of meetings and discussions between team members regarding milestones, functions, competition strategy, results of testing and team sparring, etc.
10% Design Notebook (7% Individual, 3% Team)
Show us, in your notebook, the process you undertake; explain what you are doing and thinking as your design evolves. Make notes about what works, and what doesn’t, include sketches. If you see or learn of a design alternative from a classmate, TA, instructor, etc., that you consider, make a note (in your notebook) of the source of the idea or concept and circumstances. When you test or spar with your device, make notes on what broke, what you learned, and how you applied your new knowledge.

10% Design Process and Collaboration (5% Individual, 5% Team)
This category evaluates how well you coordinated with your teammate to meet the functional requirements of the task and the size and weight constraints. It also evaluates how well you learned and practised the material from class concerning suggestions for the process of engineering design. For example, did you seriously consider several alternative designs, or did you adopt the first solution that occurred to you.
Evidence of collaborative team design is found in the notebooks as descriptions of meetings and discussions with your teammate and discussions of alternatives to alleviate problems that have arisen with your device(s).

100% Total (75% Individual, 25% Team)
Penalty-free extensions for homework assignments must be arranged in advance with the Instructor. In the absence of a pre-arranged extension, the maximum possible fraction ($M$) of the credit available for an assignment will be reduced according to the following formula:

$$M = (1 - .365)e^{-0.365D} + .365$$

where $D$ is the number of School Days the homework is late.