Topics in Product Development in Mechanical Engineering
ME 4B03/6B0
Course Outline
Fall 2017

Instructor: Khalil Abuosba, Ph.D.
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Lectures and Tutorials Location: BSB 137

Teaching Assistants:
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Calendar Description
Case studies using modern product development methods, value engineering, product specification, rapid product development, lean design and continuous improvement, product liability and robust design.

Team Work Project Course Component
The course involves a team work project for which regular attendance and collegial participation is required. Students anticipating a difficulty or requiring special accommodation with this course component must identify themselves to the instructor no later than September 11, 2017.

Course Textbook Required
(mandatory):

Optional (supplementary):

Lectures
Thursdays, 7:00pm-10:00pm, beginning Sep. 7, 2017. Corresponding textbook chapter references, and a planned weekly schedule are listed below. There will be a short break, estimated from about 8:15pm-8:30pm – relevant project lecture material as required, deliverables, team interaction Q&A etc.
**Tutorials:** tutorials are to be held on Mondays (3:30 – 4:20 pm).

**Main Topics**
1. Introduction, The World of Product Development, Team Project
5. Engineering and Finance, Value Engineering, Costs, Continuous Improvement.
7. Prototyping, Robust Design, Testing, Product Liability

**Exams Coverage**
- Mid-Term Exam: Oct. 5, 2017, 7:00-9:00pm, covering Chapters 1-8 and 19.
- Final Exam: Chapters 5-16 and 18.

**Software, Computer Laboratory, and Project Kits**
- The analytical examples used in the course were created using Autodesk Inventor (https://www.autodesk.com/education/free-software/featured).
  - The software is installed in JHE 219A computer laboratory, and access to this laboratory will be provided to all students registered in the course. If you have an adequate personal computer, you can register and download a personal version of the software. Note that technical support is not provided for installing personal software.
- The microcontroller used for the project is the Arduino Duemilanove/UNO (see http://www.arduino.cc).

**Grading**
There will be two short Discussion Papers (each 5%), one Mid-Term Test (20%), a Major Team Project (40%), and Final Examination (30%). The Mid-Term Test will be held Oct 5, 2017 during the regularly scheduled class time as noted below. The Final Examination will be scheduled by the Registrar. Permitted aids at the Mid-Term and Final Exam will be a standard 8.5” x 11” sheet of paper with course notes and the McMaster Standard Calculator. The Major Team Project is to be demonstrated during the November 25, 2017 lecture period, and the project report must be submitted no later than November 27, 2017. Students enrolled in Mech Eng 6B03 will be required to submit both discussion papers.
- The final grade will be calculated as the maximum of:
  - Case Study 1 Report: (5%).
  - Case Study 2 Report: (5%).
  - Mid-Term (20%).
  - Project (40%).
  - Final Examination (30%).
  - 50% of Discussion Paper 1 and 2 grades as a bonus (5% max) to a maximum total grade not exceeding 100%.
Discussion Papers
- To promote an understanding of the issues in product development, beyond the immediate product engineering and development itself, two short discussion papers (5% each), 500-750 words around 2 pages, with at least two reference sources, are to be written and submitted by the student (although the second is at the student’s discretion). These will be counted in the final grading on a best of basis plus 50% of the second paper as a bonus to the final grade. Topics will be posted on Avenue2Learn.

Major Team Project
- To provide a practical case study, a major electrical/mechanical/software project (40%) on customer needs/specification/design of a prototype solar photovoltaic system is to be completed in teams of up to nine students. During the term, a Team Member and Organization Brief (5%), and two Project Progress Reports (each 7.5%) are to be submitted by each team. At the end of the term, the completed project will be presented at a Trade Fair style event (10%), and a Final Report will be submitted (10%). Details are provided on separate following pages. Mech Eng 6B03 students will participate in the teams.
- Instructor and TA appointments may be established with each team to review the Progress Reports depending upon performance. Attendance of all team members at these meetings is required, and unexcused absence will incur a 2% penalty. Effective team work is an essential part of the project. Team conflict reported or observed will be collegially resolved by the instructor in consultation with the TAs.
- Most electronic components and mechanical items (standard fasteners, etc.) will be provided to the team after receipt of a $100 deposit refundable upon return of the items. Anticipate, however, that, based on the chosen design, each team may need to collectively pay approximately $50 for additional items. Moreover, non standard items which are student sourced, i.e. solar panel and some electronics such as ICs, inductors, etc. will be reimbursed project expenses with receipts to approx. $70. Rechargeable AGM 12V batteries will be provided for the demonstration.

Learning Outcomes
After successfully completing this course the student will have demonstrated the ability to:

- Describe the product development processes, its organization and participants.
- Describe the factors that influence product development and the impact of product development on the environment and society.
- Develop customer specifications into buildable engineering technical specifications.
  - Work within an engineering team to organize and manage a product development program; generate and progress product design concepts to a prototype level.
  - Select from competing engineering designs using quantifying methods.
  - Incorporate financial considerations into product development decision making.
  - Perform an engineering cost estimate.
  - Survey the literature and communicate a concise synopsis wrt topical cases in
Course Weekly Schedule
To progress the course in a timely fashion, the following weekly lecture, project workshop and deliverables schedule follows:

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<tr>
<th>Date</th>
<th>Section</th>
<th>Details</th>
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| W1 Sep 7 | Lecture | - Course Outline, objectives and logistics.  
- Chapter 1: Introduction to Product Development  
- Chapter 19: Managing Projects. |
| W2 Sep 14 | Lecture | - Chapters 2 - 4: Development Processes  
(Smith & Reinertsen).  
Types of products and their impact. Product development concept to mfg.Product planning.  
Project Workshop |
| W3 Sep 21 | Lecture | Chapters 5 - 7: Customer needs and Concept Generation.  
Concept generation, matrices, understanding customer needs.  
Project First deliverable: Project and team organization with timeline (Gantt Chart) |
| W4 Sep 28 | Lecture | Chapters 6 - 8: Product Specifications and Design Selection  
Project Workshop |
| W5 Oct 5 | Lecture | Mid Term in class (up to and including Sept 28 lecture material)  
Project Second deliverable: Customer needs, concept work ups, design proposal.  
Due Discussion Paper 1 due at start of class  
Midterm Recess No lecture, No project |
| W6 Oct 19 | Lecture | Chapter 13: Engineering and Finance  
Appendix A: Time Value of Money and NPV  
Engineering economics. Value Engineering, cost analysis and reduction.  
Project Workshop |
| W7 Oct 26 | Lecture | Chapter 18: Engineering and Finance cont’d  
Chapter 16: Patents and Intellectual Property  
Appendix B: NPV Analysis for Modeling Uncertain Cash Flow  
(Engineering decision making, investment, continuous improvement).  
Project Workshop |
| W8 Nov 2 | Lecture | Case study  
To be specified.  
Project Workshop |
| W9 Nov 9 | Lecture | Chapters 14-15: Prototyping and Robust Design (Reverse engineering, Prototypes, Testing, Product Safety, Product Liability  
Project Third deliverable: Final Designs (Mechanical/Electrical/Software), Analysis, Prototype parts review  
Due Discussion Paper 2 due at start of class |
| W10 Nov 16 | Lecture | Chapters 10-12: Product Architecture, Industrial Design, Design for Environment |
Modularity, standardization, system integration. Design for Mfg. (DFM), Design for Environment (DFE)

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<tr>
<th>Project</th>
<th>Workshop</th>
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<tr>
<td>W11</td>
<td>Project Night</td>
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<tr>
<td>Nov 23</td>
<td>Fourth deliverable: Project demonstration, Fifth deliverable (project report) due by Friday, December 1 at 5:00pm EST</td>
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<tr>
<td>W12</td>
<td>Review</td>
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<tr>
<td>Nov 30</td>
<td>Final Exam Review (U&amp;E Ch. 5 – 16, 18 and course notes)</td>
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<td>TBA</td>
<td>Final Exam</td>
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**Mandatory Policy Statements and Clarifications**

- Standard undergraduate course management policies are available at the link [http://www.mcmaster.ca/policy/Students-AcademicStudies/UGCourseMgmt.pdf](http://www.mcmaster.ca/policy/Students-AcademicStudies/UGCourseMgmt.pdf) Clarifications specific to this course are provided below.

- Avenue2Learn Website: avenue.mcmaster.ca
  - Used for student submissions, grade release, etc.

- Office Hours:
  - Thursdays, 6:00-7:00 pm

- Late work: will be dealt with on an individual basis guided by university policies.

- Attendance Expectations:
  - Students are expected to attend all course elements and participate with their team. Unexcused absence from a team Project Progress Review meeting will incur a 2% penalty. Absence or a poor grade from the Mid-Term will result in that grade being excluded, with a corresponding increase in the Final Examination component.

- Attendance at lectures is expected, and at the instructor’s discretion attendance may be taken. Unexcused frequent lecture absence will be addressed in a meeting with the instructor. Distracting cell phone, tablet, and laptop computer use is not acceptable during lectures. If you anticipate the need to monitor your cell phone for an urgent message, please sit near the lecture room entrance so that you can leave quietly. Violators will be asked to leave the room, will be recorded as absent, and the matter will be addressed at a meeting with the instructor.

- Special grade adjustments:
  - Will be dealt with on an individual basis and guided by university policies.

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**Academic Integrity:**

It is your responsibility to understand what constitutes academic dishonesty. The Academic Integrity Policy is available at the link [http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf](http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf) Clarifications specific to this course are provided below.
- You are expected to exhibit honesty and use ethical behavior in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity.

- Academic dishonesty is to knowingly act or fail to act in a way that results in, or could result in, unearned academic credit or advantage. This behavior may have serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: “Grade of F assigned for academic dishonesty”), and/or suspension or expulsion from the university.

- The following illustrates possible forms of academic dishonesty:
  1. Plagiarism, e.g. the submission of work that is not one’s own or for which other credit has been obtained.
  2. Improper collaboration with other teams. Ask the instructor or TA if uncertain.
  3. Copying or using unauthorized aids in tests and examinations.

- turnitin.com;
  - Automated plagiarism methods will not be used, and student submissions will not be retained in a database beyond the private Avenue2Learn submission and grading tool. However, the instructor and TAs may verify originality of submitted work using other verification methods.

- On-Line Element:
  - Both an online website and Avenue2Learn are used to administer the course. These tools are used to increase efficiency. Students should be aware that, when they access the electronic components of this course, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in this course will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

- Adverse Discrimination:
  - The Faculty of Engineering is concerned with ensuring an environment that is free of all adverse discrimination. If there is a problem that cannot be resolved by discussion among the persons concerned, individuals are reminded that they should contact their Department Chair, or the Human Rights and Equity Services office, as soon as possible.

- Academic Accommodation of Students with Disabilities Policy: The related policy is available at the link http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicAccommodation-StudentsWithDisabilities.pdf

- To receive accommodation in a timely manner, students must communicate requirements at the beginning of the course or as soon as possible after the need for
a special accommodation is identified. Accommodation is not offered retroactively.

- **Right to Modify Course Elements:**
  - The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.

- **Materials and Fees:**
  - A printed copy of the Ulrich & Eppinger textbook is considered to be a required course resource but will not be a permitted aid at the Mid-Term Test and Final Examination. Unless a special accommodation is confirmed, electronic versions may not be used. As noted above, a refundable $100 deposit for electronic and mechanical project kit components will be collected.
  - Teams may need to collectively pay approximately $50 for design specific additions. Certain other project expenses may be refundable as described.

**Common Sense:**
The overarching expectation in the course is that everyone shall behave with collegiality, respect for authority, common sense, and in the spirit of shared team work and achievement. Most flexible and satisfactory informal resolution of difficulties is achieved by bringing concerns to the instructor and TAs as early as possible. Confidentiality will be respected to the maximum extent possible, consistent with safety and legal reporting requirements.
Term Project Specifications

Introduction
Topics from the Ulrich and Eppinger textbook are best reinforced using an actual Needs/Specifications/Design/Build/Test project.

- To provide such an experience for this course, identification of customer needs and engineering specifications, as well as improving the mechanical/electrical/software robustness of a “works like” photovoltaic solar tracker and battery charge controller will be studied. This is a variation of a previous focus project for the course.

- The photovoltaic (PV) panel and battery charge controller are new, and although related documentation is available on the course website for the tracker, the PV panel and charge controller will require fresh development work.

- A list of students enrolled in the course (including email information) will be provided.

- You will work in Design Teams of up to nine students sub dividing responsibility for the project. Teams are pre-selected, however any individuals wishing to switch must make their own arrangement prior to September 16, 2017, and report them to the instructor not later than September 16, 2017. Each group must contain at least three Mechanical Engineering students and three Mechatronics Engineering students. The project involves mechanical, electrical, and software design, so it is an advantage to have strong representation from both disciplines. Each team must name a permanent leader/manager who will be the main interface with the instructor/TAs. In cases where more than one team member wishes to lead, the team will need to justly decide on who assumes the leadership position. The course instructor may assist in this situation. Effectiveness of team member communication will be observed by the instructor/TAs at mandatory project assistance workshops and meetings, and as documented in the final report submission. Where difficulties are observed, the instructor/TA may convene additional team meetings to resolve the concerns. The team will submit a single final project report. Team member technical roles will be finalized at the time the leader is chosen. The team leader/manager is expected to technically contribute at a level nearly similar to other team members. Each team member is expected to contribute as agreed, and honestly and completely document their contribution in the project final report.

- As noted in the textbook, the material covered is targeted for senior undergraduate level and graduate level students. Significant personal maturity is expected from everyone.

- Cooperation with the instructor, TAs and department technical staff is mandatory. In cases of serious disagreement or observed lack of progress the instructor will not hesitate to invoke appropriate university conflict resolution solutions.

General Scenario
You and up to eight colleagues have just been handed the pieces of an unfinished program to develop a solar heliostat tracker. Recognizing the current consumer interest in solar energy and the opportunity afforded by a new government program promoting small scale solar power generation, you decide to test the waters with the planning, design, build and exhibition of a demonstration scale model for a solar powered battery charging system at upcoming trade show.
- A previous organization developed a solar heliostat prototype device that tracks the sun (solar vector) and redirects solar radiation to a fixed, ground based target. It is based on a battery backed up real-time clock that provides the time of day, an ArduinoDuemilanove/UNO microcontroller, an accurate software algorithm that, given latitude, longitude, and time of day will compute the solar vector Azimuth and Zenith angles, stepper motor interfaces, and a two axis mechanical scale model implementation. Full details are contained in the report provided on the course web site.

- Needs and specifications challenges from the prior program arose because of lacking customer validation and a misunderstanding of the market. The net result of such an error was a product without a customer. You are reworking the product for a new market opportunity - photovoltaic power generation.

- The additional technical development challenge involves the addition of a photovoltaic cell and battery charge controller to demonstrate the daytime solar charging of a small storage battery as the unit tracks the solar vector. Prior technical development challenges were centered in robustness difficulties. Specifically, loose mechanical bearings and assembly tolerances were causing deviations from CAD nominal. This results in tracking errors and wind load vibrations. Incorrect latitude and longitude data entry, poor leveling, and misalignment with true north collectively cause additional tracking errors which may not be easily tolerated by a fixed ground target. Direct solar vector tracking is more tolerant and thus somewhat easier to implement.

- As is common in the high-tech industry, the team challenges were amplified by the technical development frustrations. Mechanical blamed electrical. Electrical blamed software, etc. The team leader was unable to overcome the conflict and so the program was shelved.

- The instructor/TAs will provide consultation during regular project assistance workshops and meetings, with emphasis on early stage needs and specifications related advice. Department technical staff will assist by providing rapid prototyping services, supplying standard fasteners, small components (if available) etc.

**Materials Provided**

For physical prototyping purposes, you will be provided with the following items:

- Arduino Duemilanove/UNO microcontroller
- USB cable to connect to PC/Mac
- external 9 volt, 1000 mA power supply for the Arduino and clock time source
- expansion (shield) circuit board containing stepper motor drivers, etc.
- set of homing switches, limit switches, connecting cables, etc.
- Azimuth stage kit including turntable and bearing, worm gear drive, stepper motor, etc.
- stepper motor including mounting bracket for use on the Zenith angle stage
- A $100 per team deposit is required for the items, and will be refunded when the items are returned. Prototyping services are available for part manufacture. Fees are listed on the course web site, and it is suggested that the group keep expenses below $50. PV panels and other specific components like ICs which the team will
have to source may be reimbursed with receipts. Storage batteries will be made available for the demonstration event.

**Materials to Source**

- For physical prototyping purposes, you will be required to source the following items:
  
  o A solar photovoltaic cell (without any integrated charge control) with a power rating of approximately 4W-5W of a size which will be suitable to be reliably supported by the solar tracker base, azimuth stage kit provided above, and elevation device that your team will design and build.
  
  o A battery charge regulator device(s) or controller IC device.
  
  o Small electronic passive components, resistors, capacitors, inductors, any switches, indicators and such, and prototype project circuit board for the above. Some components may be available from the electronics shop.
  
  o Small mechanical components, nuts, screws, washers etc. may be available from the mechanical shop.
  
  o A cost target of $70 is anticipated. Teams should retain all project receipts for reimbursement by expense claim, similar to the 4th year “Capstone” project.

**Expected Minimum Requirements**

The team must present a plausible customer validation case for the proposed product, including customer needs, concept generation (work up) and design proposal (mechanical and electrical). This is to be documented in the Second Deliverable (written report).

- The final concept selection is to be documented in the Third Deliverable (written report), including CAD “looks like” mechanical models at proposed product scale, electronic circuit schematic diagrams, software source code outline, any analysis and prototype parts.

- To demonstrate the product, a table top “works like” model is to be constructed and demonstrated. Each team will be provided with the mechanical Azimuth stage (Fig. 1(a)) and related components listed above.

- The team is to create and demonstrate a essentials only “works like” Zenith (or elevation) stage (similar to Fig. 1(b)) supporting the photovoltaic panel connected to the charge controller module and storage battery.
- A field setup procedure shall be developed to install the tracker to be level, point to true north, have correct latitude and longitude, etc. The tracker must recover gracefully from loss of power, nightfall, cloudy and stormy weather, etc (favorably implemented or specified as optional feature).

Submission Procedures
- Additional reference materials related to this project may be available on Avenue2learn from time to time. The team leader shall be responsible for on-time electronic submission of materials. If you have sketches, etc. scan them to PDF. Autodesk Inventor must be used for CAD models. Submissions must be appropriately collated into a WinZip archive containing PDF, DWG, IPT, IAM, TXT, and MP4 files as appropriate.
- Do not use other file types. Each submission must contain a brief Summary Report that provides an overview of the submission including a list of contents. Include the Summary Report in the WinZip, and submit a paper copy at the lecture. The paper copy will be graded and returned during a subsequent project workshop session. In cases of difference between the electronic submission and printed copy, the electronic submission will prevail.

Project Deliverables (Dates and Details: A2L)
- First Deliverable (5%): Team Members Formation (including Leader) and Organization, Timeline (Gant Chart), and a brief problem statement.
  o Any remaining enrolled students will be assigned to teams by the Instructor.
  o A follow-up team meeting with the instructor / TA may be scheduled.
- Second Deliverable (7.5%): First Written Progress Report (Requirements/Concept Generation/Design Proposal).
  o A follow-up team meeting with the instructor / TA will be scheduled
- Third Deliverable (7.5%): Second Written Progress Report (Mechanical/Electrical/Software Design)
  o A follow-up team meeting with the instructor / TA may be scheduled
- Fourth Deliverable (10%): Product Demonstration Event.
- Fifth Deliverable (10%): Final Written Report (Summary with CAD/Circuit Schematic(s)/Source Code Appendices).
  • A follow-up team meeting with the instructor / TA may be scheduled. The project evaluation significantly values demonstration and documentation of successful team interaction and design processes based on the course. Projects that do not follow the process steps in sequential order will not be graded.

Students enrolled in Mech Eng 6B03 are required to participate in all course activities listed for Mech Eng 4B03 students, including the Mid-Term Test, Final Examination, and participation as an active group member in the Solar Tracker Project. Mech Eng 6B03 students must complete the additional work described below. The grade for a Mech Eng 6B03 student will be calculated as Two Discussion Papers (7.5% each, 15% total), Mid-Term (20%) + Mech Eng 4B03 Project (35%) + Final Exam (30%). The second discussion paper bonus will not be available, both papers must be submitted.
Fig. 1. Scale Model: (a) Azimuth stage (provided); (b) Zenith stage (to be designed). The Zenith stage shown includes a Position Sensing Device (PSD) for fine tuning, not part of this project. The Zenith stage will carry the photovoltaic cell (Solar Panel). Reference documentation is available at the course web site.