Instructor: Dr. M. Biglarbegian

# ENGG 3490

# Introduction to Mechatronics System Design

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**Technician**: Mr. Nathaniel Groendyk
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**Class Hours:** Monday/Wednesday/Friday, 11:30am-12:20pm, MACK room 226
**Labs:** Monday, Wednesday 3:30 pm-5:20 pm, THRN Room 2307

**Midterm Exam**: 7:00pm - 9pm, Friday March 1, Rozh. 103

**Final Exam**: 11:30am - 1:30pm, (2013/04/17), Room TBA

## 1. Course

**Outlines:**

This course covers an introduction to mechatronics systems. Mechatronics, in general, is involved with mechanical, electrical and computer systems. Recently, mechatronics have found a variety of applications in many fields especially in automation and manufacturing industries. In this course, you will learn about mechatronics systems: how are they designed and controlled. We will cover programmable logic controller (PLC), review and modeling of mechatronic systems, sensing and measurement, sensors and applications, actuators and their applications, modeling and control of electric motors (dc and ac), as well as stepper and servo motors. You will learn important concepts such as analog/digital or digital/analog conversion. Microprocessors and microcontroller structures will be introduced and discussed. As well, some control techniques for mechatronic systems will be introduced, and finally mobile robotic systems and their recent advances will be reviewed. By the end of the term, you should have a good understanding of design, modeling and control of mechatronic systems. This course

contains theory and practical applications of those systems. More importantly, the course has hands-on and practical projects which provide you with great skill sets required to succeed in your career. This course covers the following topics:

1. Introduction to mechatronic systems: basics
2. Sensors and instrumentation
3. Modeling of Mechatronics systems
4. Response
5. Actuators and Motors
6. Microprocessor and microcontroller
6. Programmable logic controller (PLC)
8. Control
9. Robotics: mobile robots

**1. 1. Course evaluation**

The breakdown of the marking scheme is:

1. Midterm exam 15%
2. Quizzes 5%
3. Project and report 45%
4. Lab 5%
5. Final exam 30%

**Important Notes:**

**1.** Both midterm and final exams have questions and problems. Questions are related to the fundamental understanding of the concepts taught in class. You are allowed to bring your own **only one-page** aid sheet A4 size, (you can write on both sides) which can **only** have formulas (**No** solved problems, no derivations, no description, no explanation, no figures, no diagrams, no graphs, no curves, no tables, no units, etc.). **Important note: ANY deviations** from this will result in automatic deduction of 40% of your exam mark.

**2. Midterm Remarking**: You only have **one week** to ask for remark after the midterm is returned. Beyond that, nothing will be accepted.

**3**. There will be two or three quizzes during the semester. The actual date for the quizzes will be announced **in the class** one week prior to the quiz. **It is the student responsibility** to show up during the lectures to know the quiz date. **There is absolutely no make up for quizzes.** You only have **three days** to ask for remark after the quiz is returned. Beyond that, no adjustment for marking will be accepted.

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**References:**

There is no single textbook that can cover all the material taught in a Mechatronics course in general, simply because Mechatronics is multidisciplinary. The followings books are great sources:

1. "Mechatronics: A Multidisciplinary Approach", W. Bolton, 5th edition, Prentice Hall, 2011.
2. "Applied Mechatronics", A. Smaili, F Mrad, Oxford University Press, 2008.
3. "Programmable Logic Controllers", Frank D. Petruzella, 3/E, McGrawHill, 2005.
4. "Mechatronics", Dan S. Necsulescu, Prentice Hall, 2002.
5. "Principles of Robot Motion", H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki and S. Thrun, MIT Press, Boston, 2005
6. "Principles and Applications of Electrical Engineering", by G. Rizzoni, McGraw-Hill, 5th edition, 2007.
7. "Electric Machinary Fundamental", by S. J. Chapman, McGraw-Hill, 5th edition, 2011.
8. "Programmable Logic Controller", J. R. Hackworth, F. D. Hackworth, Jr., 4th edition, Prentice Hall, 2004.

**University Policy on Academic Misconduct:**

Academic misconduct, such as plagiarism, is a serious offence at the University of Guelph. Please consult the Undergraduate Calendar 2011-2012 and School of Engineering programs guide, for offences, penalties and procedures relating to academic misconduct.
http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml

**Disclaimer:**

The instructor reserves the right to change any or all of the above in the event of appropriate circumstances, subject to the University of Guelph Academic Regulations.

# 2. Project

The primary objective of the course is to provide students with hands-on experience in applying principles of engineering design to simple projects. Through application of formal design procedures, students will gain hands on experience in effective decision making and execution of engineering design.

**Note1**: Each group consists of at least 5 people (6 at most). Each group **must** contain **at least** one mechanical and one ES&C student. This is to ensure that each group could be able to do mechanical parts and programming efficiently to be able to complete the project milestones.
**Note 2:** There is no late policy for the final demo. Late demonstration is not acceptable. Each group needs to demonstrate their project (whatever they have done by the deadline).

Table 1(a): Important dates

| Item | Assigned / Start | Due / Finish |
|---|---|---|
| Proposal and material selection | Jan 7 | Jan 21 (all the class) |
| Sorting Mechanism | Jan 7 | March 25/March 27 |
| Final Design Report | --- | **March 28** |

Table 1(b): Project Completion Intermediate Milestones

| Milestones | Due / Finish |
|---|---|
| Interfacing Sensors (IR, Hall effect, LED, touch sensors etc.) | Feb 11/Feb 13 |
| Nuts loading Station | March 6 |
| All machining parts complete | March 18/March 20 |

Report deliverables will be marked based on the requirements detailed in the Report Deliverables Section. All reports are to be submitted on-time. The design will be scored such that the best design in each category will receive the highest mark for that respective category.

# Sort and Feed Mechanism Project

### 2.1. Project description

For the course project you are required to design a nut sorting mechanism that is capable of separating four types of nuts: small steel nuts, medium brass nuts, large brass nuts, and large nylon nuts. Please visit the course webpage on the Courselink for information about the dimensions and weights of the nuts. The sorting mechanism should be able to identify the type and size of the nut and then feed it into correct container for shipping. In total, you will be required to sort 12 nuts, 3 of each class. The nuts will be initially loaded in an arbitrary order and the mechanism should be able to separate them correctly and dispose every nut in the correct container. **You are required to design the loading station as a part of the sorting mechanism**. Containers used resemble coffee mugs and have the dimensions listed below. Your sort and feed mechanism should be placed on a platform table with dimensions given in the figure below. **Every group is required to design their own platform table** using wood, Plexiglas, etc. (should conform to the dimensions provided below). Each group will be provided with a design kit that includes a microcontroller and several types of sensors. Groups are strongly encouraged to utilize the kit to design the nut sorting mechanism.

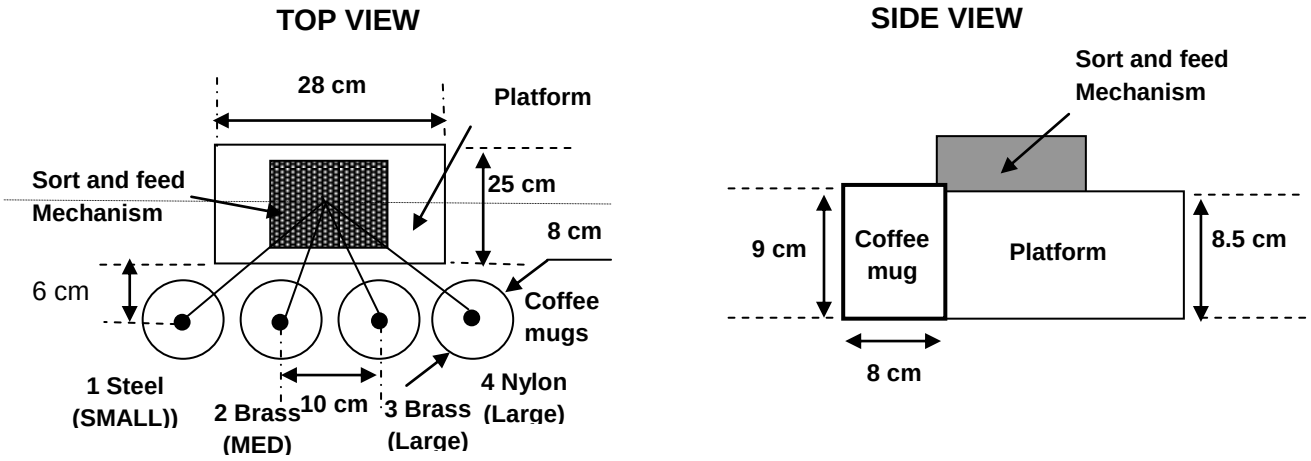


Fig 1: required layout of the packaging stations

**2.2. Project Kit**

Each group will be provided with a kit that consists of an Arduino board plus some sensors and switches. The project kit with all the items must be returned at the end of the term. In the first three weeks during the lab sessions, the TA will introduce the Arduino board and provide the students a training on how to work with the board, implementing sensors, to help familiarize the students with the microcontroller board which will cover: (1) integration of components onto the Ardunio board, (2) installation of board software and programming the controllers, (3) interfacing sensors and actuators, (4) implementation of position/velocity control for actuators/motors, and (5) troubleshooting tips and instructions for proper use of the microcontroller and peripherals.

The course project kit includes the following. Note that some additional equipment is available from the lab technician upon request:

(1) Arduino Mega 2560 (http://arduino.cc/en/Main/ArduinoBoardMega2560)
(1) Breadboard
(1) Wiring & Resistor Kit
(1) Multimeter
(3) 5/16" Steel Nuts
(3) 3/8" Brass Nuts
(3) 3/4" Brass Nuts
(3) 3/4" Nylon Nuts
(1) 0.25" Magnet Square (https://www.sparkfun.com/products/8643)
(1) Flexiforce Load/Force Sensor (http://www.digikey.ca/product-search/en/sensors-transducers/force/1966743?k=30056-ND)
(1) AD22151 Linear Output Magnetic Field Sensor (http://www.digikey.ca/product-detail/en/AD22151YRZ/AD22151YRZ-ND/936656)
(2) VT43N3 500 kΩ, 400 mW Photoconductive Cell (http://canada.newark.com/excelitas-tech/vt43n3/ldr-500kohm-400mw-vt400-series/dp/96F9263?Ntt=96F9263)
(1) Sharp GP2D12 Infrared Range-Finder (http://www.sharpsma.com/webfm_send/1203)
(1) Sharp GP2D120 Infrared Range-Finder (http://canada.newark.com/sharp/gp2d120xj00f/sensor-distance-analogue-o-p/dp/97K0574?Ntt=97K0574)
(1) Sharp GP2Y0A02YK0F Long Range Infrared Range-Finder (https://www.sparkfun.com/products/8958)
(1) Negative Temperature Coefficient (NTC) Thermistor (http://canada.newark.com/epcos/b57891m103j/ntc-thermistor/dp/21C9772?Ntt=21C9772)
(1) Maxbotix LV-EZ1 Ultrasonic Range Finder (https://www.sparkfun.com/products/639)
(1) 9 Degrees of Freedom Sensor Stick, Contains Accelerometer, Magnetometer, and Gyro (https://www.sparkfun.com/products/10724)
(1) Interlink Electronics 0.2" Circular Force Sensing Resistor (FSR) (http://www.robotshop.com/productinfo.aspx?pc=RB-Int-01&lang=en-US)
(1) Break-Beam Optosensor (http://www.robotstorehk.com/H21A1.pdf)
(4) HS-645MG Servo Motors (http://www.robotshop.com/ca/productinfo.aspx?pc=RB-Hit-29&lang=en-US)

(4) Texas Instruments L293NE IC Motor Drivers (http://canada.newark.com/texas-instruments/l293ne/ic-motor-driver-half-h-1a-dip-16/dp/06F9524?Ntt=06F9524)
(3) 4V, 1.2 A, 36oz-in Unipolar Stepper Motors (http://www.robotshop.com/ca/productinfo.aspx?pc=RB-Soy-01&lang=en-US)
(3) Cytron 3-40V, 2A Unipolar/Bipolar Stepper Motor Controllers (http://www.robotshop.com/ca/productinfo.aspx?pc=RB-Cyt-23&lang=en-US)
(2) Texas Instruments LM741 Operational Amplifiers (http://www.ti.com/lit/ds/symlink/lm741.pdf)
(2) Omron Electronic Components D2F-L Hinge Lever Micro Switch (http://canada.newark.com/omron-electronic-components/d2f-l/micro-switch-hinge-lever-spdt-3a/dp/36K7258?Ntt=36K7258)
(1) 4" Stroke 150 lb Force Linear Actuator (http://www.robotshop.com/productinfo.aspx?pc=RB-Fra-14&lang=en-US)
(1) Texas Instruments OPT101P Photo Diode and Transimpedance Amplifier (http://canada.newark.com/texas-instruments/opt101p/ic-transimpedance-amplifier-2mhz/dp/75C5222?Ntt=75C5222)
To be Added Upon Arrival:
(1) Hamlin Hall Effect Magnetic Sensor (http://canada.newark.com/hamlin/55100-3h-02-a/hall-effect-magnetic-sensor/dp/50H8225?Ntt=50H8225)

**Important Note**: You are allowed to only use the items in the kit that will be provided to you. In addition, each group can purchase **ONLY one** extra **sensor/actuator which is worth up to $20** from their own pocket, if needed. The need for this sensor/actuator MUST be clearly stated and justified in the final report. Note that the original receipt must be attached to the final report (no photo copies is accepted). This is to ensure fairness to all the groups. **Note that using the extra that costs more than $20 will result in 25% deduction of your mark**. The importance of this project is to familiarize and prepare you to work with a limited budget, which is the case in real-life projects.

### 2.3. Fabrication and Safety

Modification and assembly of materials may be carried out in the student machine shop. Students will be allowed to access the machine shop **ONLY during the weekly time slots identified by the course instructor**. No exceptions will be made under any circumstances. Moreover, the final competition will be held in week 11 to encourage students to access the machine shop early in the term to complete the course requirements and avoid the "rush" of weeks 10-11 when other teams require access to the shop during the same time period to complete their respective term projects.

For student and machine safety, power tools available to students will be restricted and **Does NOT** include use of the milling machines or lathes.

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**Machine shop and safety**:
Each group is allowed to use **up to $50** worth of material from the machine shop. It is therefore important to be very careful when selecting the material that you use for your project.
In your proposal, you should attach a list of the materials that you might think you need from the following website:
http://www.metalsupermarkets.com/msc-home.aspx
- Select your material
- Select your shape
- Select your grade
- Select your size

To get a true estimated cost: under 'Dimension' box, input 96 inch and under 'Quantity' box input (1) and then press the "Enter" key to get the cost (note: after you press the 'Enter' key wait for a few seconds!). Then, divide the obtained cost by 96 to get a 1inch, "constant" price.
* If you need advice on how to select the material for your design, please see Ken or David at the machine shop.

The following time slots have been booked for using the machine shop:
**Tuesdays**: 8:30 am-10 am, 11:30 am-12:30 pm
**Thursdays**: 8:30 am-10 am, 11:30 am-12:30 pm
**Wednesdays**: 3:00 pm-4:30 pm
Important note: Students are allowed to use the machine shop **ONLY during these time slots**. Access to the machine shop at any other time **will NOT be allowed**.

Please note that equipment in the shop pose potential dangers for both operators and those in the vicinity. While reasonable efforts have been made to ensure and educate students about safe operation, caution must be exercised when working in the shop. For safety, students are required to adhere to all rules and regulations pertaining and posted in the shop. If there are any concerns regarding safety or suggestions to improve safety, please bring them to the Professor's or TA's attention as soon as possible.

**Late policies** for the **final** project report:

- Both **hard and soft** copies are required for submission. Reports should be submitted to the TA and are due by 5:30 pm on March 28th.

-25% deduction if the final report is submitted late within 24 hours of the deadline (i.e. within 1 day **by 5:30 pm**)
-50% deduction if the report is submitted late within 48 hours of the deadline (i.e. within 2 days **by 5:30 pm**) reports are not accepted beyond that (i.e. grade of 0)

**Remarking**: You only have **three days** to ask for remark after the final report is returned. Beyond that, no adjustment will be made.

**2.4 Report Deliverables**

Proposal and Material Selection (Due Date: **January 21)**

- Proposal: The purpose of the proposal is for each group to describe their approach to the problem and outline their plans and management strategies. Effectively, the proposal should ensure the client in your ability to complete the project successfully, efficiently, and economically. The proposal should not be longer than 3-4 pages.
- Material Selection: If you need material from the machine shop (please see Page 7 section "Machine shop and safety" on how to order), you must submit this on a separate page.

* Both proposal and material selection are due during class.

Final Design Report (Due Date: **March 28st**)

The purpose of this report is to communicate the progress leading up to your group's resulting design. It will detail your design specifications, explaining calculations and analyses that ensure that your final design meets specifications. It should also include all microcontroller program code and a description of the logic you used to separate and sort the nuts. Any further testing, simulation, and results should be detailed and discussed. In addition, this report will also include changes to budgetary and scheduling plans. While the report should be comprehensive and include all the necessary information, it should not exceed **10 pages**. Appendices and codes are not counted toward the 10 page limit.

**2.5 Project marking**

The project demonstration will be marked out of **35**. The mark breakdown depends on the following categories: (1) design (**15%)**, (2) performance (**12%**), and (3) speed of sorting (**8%**).

**Design (15%)**

The first category is broken down into 4 subcategories as outlined in the table below

Table 3: Design category Marks Weighting

| Subcategory | Weight |
|---|---|
| Relevance to Mechatronics Design | 5 |
| Conformance to Dimensions specifications | 3 |
| Footprint of the Mechanism | 4 |
| Quality of Design – machining | 3 |

**Relevance to Mechatronics Design**: your design will fall in one of three categories; (a) mechatronics, (b) mechanical, or (c) manual. A mechatronics design utilizes sensors to correctly sort all the nuts fed in random order. A mechanical design **MAY NOT** utilize sensors to sort the nuts and can only use actuators and machined channels (e.g. pinball machine) to accurately sort the nuts. ENGG*3490 main emphasis is one mechatronics design and hence a mechanical based design will be only awarded 3/5 in the "Relevance to Mechatronics Design" subcategory. Finally, a manual design that utilizes neither the microcontroller nor the sensors and actuators provided in the kit will be awarded 2/5 in this category.

**Conformance to Dimensions specifications:** groups should design their sorting mechanism to conform to the dimensions specified in page 3. Maximum tolerances of 8% for every dimension specified will be allowed with no penalty. The centre points of all four coffee mugs can be organized in a horizontal line or arch as long as the spacing dimensions mug-to-mug and mugs-to-platform are preserved. If you elect to organize the coffee mugs centers along an arch, the spacing dimensions will be as shown in the Figure below. Failure to produce a design that satisfies the above requirements will result in 2 marks deduction in this subcategory.

$O$ is the center of your mechanism

$OA = OB = OC = OD = 23cm$

$\alpha = 28^\circ$

$\beta = 50^\circ$

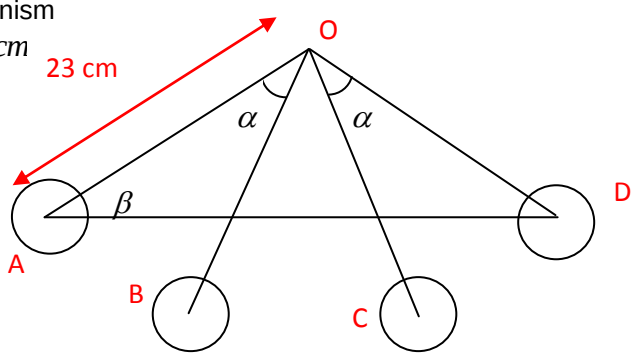


Fig. 2: Layout of the packaging stations

**Quality of Design – machining:** Your final sorting mechanism should be the product of systematic application of a well thought out design process that meets the project requirements. Your final design should reflect this fact and hence poorly machined parts or subsections of the mechanism that are products of "last minute" tweaking to ensure the objective is met will not be looked at favorably during the final evaluation. Your design should demonstrate that considerable time has been allocated to the implementation of the predefined design process. Also, your final product should reflect the fact that time was spent in the machine shop to ensure the integrated sorting mechanism is robust and was not put together in a rush to meet the competition deadline. Poorly-machined or integrated parts in your final design may result in 1-2 marks deduction in this subcategory.

**Performance (12%)**

This category relates to efficiency of the sorting mechanism. At the end of sorting, each mug should have 3 nuts that belong to this container category. For every container, an inspection will be performed at the end of sorting to count the number of nuts and their types. For every nut that does not belong to a specific container a total of 1 mark will be deducted. For example if a sorting mechanism places 3 correct nuts in container 1 (3 steel small), 2 correct in container 2 (2 brass medium and 1 brass large), 2 correct in container 3 (2 brass large and 1 nylon large), and 2 correct in container 4 (2 nylon large and 1 brass medium); a total of 3 marks will be deducted and the groups' grade in this category will be 9/12. An empty container results in 3 marks deduction for this container. Also, at the end of sorting for every container having 2 or 4 nuts (of any combination) will result in 1 mark deduction. Every container having 1 nut or 5 nuts as

opposed to 3 will result in 2 marks deduction. If the sorting of all 12 nuts is done correctly, a full mark of 12/12 is guaranteed in this category.

**Speed (8%)**

The third category depends on speed of sorting.

- For groups that scored 12/12 in performance, a full mark of 8/8 in speed will be awarded to the group that completes the "correct" sorting in the fastest time. The group that requires the longest time to correctly sort 12 nuts will receive a mark of 4/8 in this category. The mark for all other groups (that successfully completed category 2) will be spanned linearly between 8/8 and 4/8.
- All groups that fail to score 12/12 in performance will be placed in a separate poll for evaluation for speed. They will be ranked based on speed of sorting and their mark in this category will be calculated as (mark in performance/12)*(8)*($\frac{\text{speed of fastest group in the pool}}{\text{recorded speed of the group}}$).

# 3. Labs

There are three formal lab sessions organized at the beginning of the term. The first lab (Lab 0) is meant to serve as a brief introduction to the lab portion of ENGG*3490. Groups will be formed during the introductory lab session and should consist of 5/6 students, with one ES&C and one Mechanical student in each group. Students will work in the same groups for both the labs and project. After groups have been finalized, project kits and lockers will be allocated. Lab 1 and Lab 2 will present the basics of working with sensors and motors and include a corresponding report which must be submitted by each group. The lab reports are due in the lab sessions and the TA will go over the deadlines as they occur. Reports are usually due the week following the lab (i.e. Lab 1 is performed in Week 1 and the report is due in Week 2 as Lab 2 begins).

Lab descriptions and presentations will be posted on Courselink as the term progresses.

**Late policies**:

- Both **hard and soft** copies are required for submission. Reports should be handed to the TA in the lab session.

-25% deduction if the report is submitted late within 24 hours of the deadline (i.e. within 1 day by **5:30 pm**)
-50% deduction if the report is submitted late within 48 hours of the deadline (i.e. within 2 days **by 5:30 pm**) reports are not accepted beyond that (i.e. grade of 0)

**Note**: Grouping for the labs are also done in the first lab. For remarking the labs and projects, please discuss with the TA in the lab.

**Remarking**: You only have **three days** to ask for remark after the report is returned. Beyond that, no adjustment will be made.