SYLLABUS: Physics First Year Seminar – Fall 2023 [0th Draft]
Introduction to Mechatronics

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Lecture: Phillips 247 MW 10:10a–11:25
Lab: Phillips 220 M (1:25p or 3:35p)
Office Hours: TBD
Teaching Asst: Shailesh Giri

Required Materials:
- There are no required materials (or textbook) for this course, other than possession of a laptop computer (Windows/OSX/Linux) with wireless capability.
- Canvas: look for the course tabbed as PHYS55.001.FA23
- Makerspace Access – see Canvas announcement posted and also early lectures.

Prerequisites: High-school math and reading/writing skills.

Course Overview and Goal: *Introduction to Mechatronics* is an introduction to important skills and knowledge required in the STEM fields of today and tomorrow, from academic, career, and social perspectives. All students, regardless of their educational goals, will achieve critical introductory skills in numerical reasoning and analysis, engineering design and prototyping, computer programming and electronics, and will demonstrate proficiency and knowledge about topics that impact society. The course focuses on four areas:

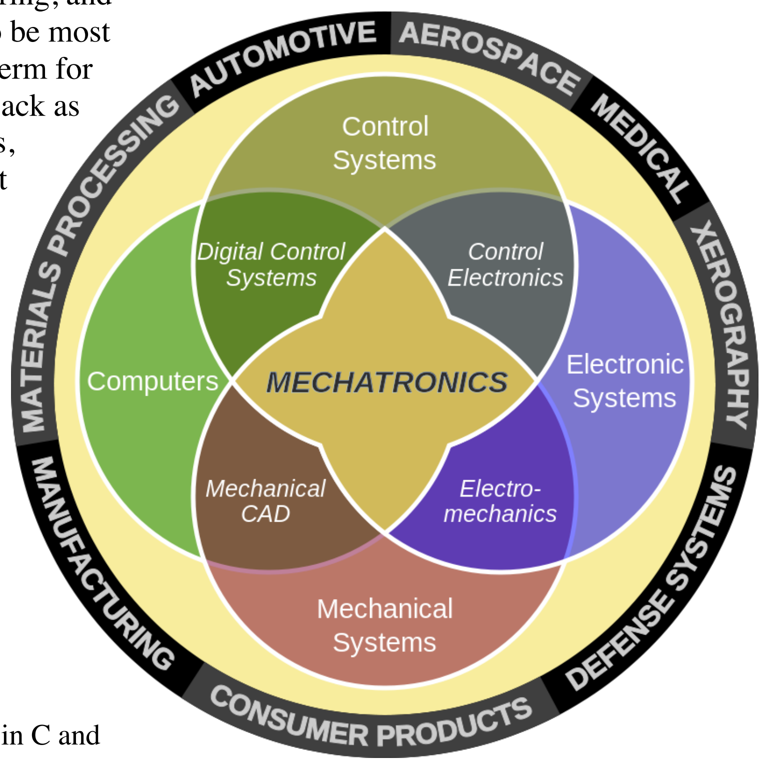
- *Numeracy* and *Statistical Reasoning* (mathematical content)
- *Engineering Design and Rapid Prototyping and Manufacturing* (Makerspace)
- *Computer Technology* (Programming and Electronics)
- *Social Aspects of Mechatronics* (aka "*please welcome our benevolent robot overlords*")

A particular focus of the last item in this list is Artificial Intelligence, Neural Networks and Machine Learning, and possibly Quantum Computing if time allows. The obvious addition to the is course compared to earlier versions is the impact of the LLM (large language model, aka ChatGPT). In some cases, our topics will be covered in parallel. Although not necessarily obviously related to one another, most topics will be introduced early, but some details will be left for the latter part of the semester. The course goals are to prepare students for academic success at UNC, help science students be more capable scientists, and to help ALL students be stronger and better-informed citizens of the technological world. Students who successfully complete this course should be positioned to begin their UNC majors in the fields of physics, chemistry, computer science, environmental science, neuroscience, applied mathematics, biomedical engineering, and others. Students outside of these traditional STEM fields will become cross-disciplinary and learn to see their fields from new perspectives. The Learning Outcomes for this course are listed on the next page and are drawn from the focus capacities of Natural Scientific Investigation, Quantitative Reasoning, Empirical Lab Investigation, Creative Expression, and Ways of Knowing found at:
https://curricula.unc.edu/curriculum-proposals/cim/ideas-in-action-slos-recurring-capacities/

Learning Outcomes

1. Connect with a faculty member early in the educational process.
2. Learn intensively among a small cohort of students.
3. Analyze and communicate issues associated with a specific, advanced topic.
4. Produce knowledge through self-directed inquiry and active learning.
5. Demonstrate the use of scientific knowledge, logic, and imagination to construct and justify scientific claims about naturally occurring phenomena.
6. Analyze and apply processes of scientific inquiry as dictated by the phenomena and questions at hand.
7. Evaluate science-related claims and information from popular and/or peer-reviewed sources.
8. Identify, assess, and make informed decisions about ethical issues at the intersections of the natural sciences and society.
9. Summarize, interpret, and present quantitative data in mathematical forms.
10. Develop or compute representations of data using mathematical forms or equations as models and use statistical methods to assess their validity.
11. Make and evaluate important assumptions in the estimation, modeling, and analysis of data.
12. Apply mathematical concepts, data, procedures, and solutions to make judgments and draw conclusions.
13. Synthesize and present quantitative data to explain findings or to provide quantitative evidence in support of a position.
14. Frame a topic, develop an original research question or creative goal, and establish a point of view, creative approach, or hypothesis.
15. Obtain a procedural understanding of how conclusions can be reached using appropriate evidence.
16. Evaluate the quality of the arguments and/or evidence in support of emerging ideas.
17. Communicate findings in a clear and compelling ways.
18. Critique and identify the limits of the conclusions and generate ideas for future work.
19. Compose, design, build, present, or perform a work that is the result of immersion in a creative process.
20. Explain the roles and influences of creativity, technologies, materials, and design processes in the creation of knowledge, expression, and effective solutions.
21. Evaluate creative work to demonstrate how critique creates value in creative domains.
22. Recognize and use one or more approach(es) to developing and validating knowledge of the unfamiliar world.
23. Evaluate ways that temporal, spatial, scientific, and philosophical categories structure knowledge.
24. Interrogate assumptions that underlie our own perceptions of the world.
25. Employ strategies to mitigate or adjust for preconceptions and biases.
26. Apply critical insights to understand patterns of experience and belief.

What Is Mechatronics? While first developing the idea for this course, my personal prediction was that virtually everyone in a university or technical setting would have at least casually encountered the term *mechatronics*. I was wrong. Based on anecdotal surveys amongst science students, those somewhat technically oriented, and lay people, only maybe 50% had ever heard the term, much less know what it means. A Wiki definition, in part, suffices for now: *Mechatronics* is a fusion of electronics, engineering, and programming (see Venn diagram), and seems to be most commonly thought of as a successor or sibling term for *robotics*. The name was coined in Japan as far back as 1971 (modern Japanese culture often sets curves, some of them quite mysterious, ahead of the rest of the world).



Regardless of what the term means, you'll be learning things that are quite recognizable to those with actual degrees in *Mechatronics*, and your experience will be relevant to anyone in your field, regardless of what your field is.

What is missing from this Venn diagram is a *social component*. This unique addition to the course is designed to be forward-thinking and provocative.

Learning Objectives: at the end of this course, students will be able to do the following:

- Write and analyze elementary programs written in C and Python.
- Control simplistic sensors and output devices with a microcontroller.
- Use smartphone telemetry for simple physics experiments.
- Build elementary electronic circuits and understand the basic quantities of voltage, current, and impedance.
- ~~Perform simple probability experiments and explain the statistical background behind the results~~.
- Train and certify on tools in the Makerspace (typically laser cutters and 3D printers).
- Design a 2D kinematic object in simulation software and then build a working example using Makerspace resources.
- Explain the basic landscape of Artificial Intelligence: history, present, and possible future.
- Build simple neural networks in software to perform classification and "deep learning."
- ~~Evaluate and comment on basic references to Quantum Computing seen in today's media and popular press~~.
- Analyze and evaluate the possibility that your existence is merely a computer simulation.
- Choose a topic of immediate interest and impact to society (e.g., the computer-brain interface; the surveillance state; truth and fiction; love and death; the future employment landscape; or the technological singularity) and analyze/evaluate your place within.
- And even more!

New Learning Objective: the world of ChatGPT.

Course Format: The course consists of a lecture that meets twice a week for 75 minutes and a lab that meets once a week for ~2 hours (4 CR). Although the labs are listed as 2 hours, they will not generally be that long; in addition, some labs will not look like actual labs – instead, they will be devoted to group work, training, or may occur in the lecture classroom.

Both the lectures and the labs will have a strong peer-interactive component – students will interact with the instructor and each other during the lecture time. Activities will include the pondering of divergent questions, short-duration group work, think-pair-share exercises, and discussion with the instructor as well as each other. Labs will have a teaching assistant (TA) and are designed so that students can complete assigned work during the lab period, with enough proficiency that they can complete extensions or further explorations outside of the lab. In all cases, collaboration and discussion will be encouraged.

Several evaluation assignments will be given in the first 10 days, so that you can decide if the course is a good fit for you. This early and aggressive pace is NOT indicative of the entire course – although the early assignments may seem impossible to accomplish, we're merely exposing you quickly to the types of skills you will be learning. If you consider dropping the course, we strongly request that you speak to the instructor first.

Social Distancing and Masking: The university is again now operating "normally;" however, no one should think that we're not still impacted by the pandemic. You are more than welcome to wear a mask in class, and the instructor may wear a mask depending on circumstances. Social distancing in the lecture can be accommodated, but such distancing may be difficult in the lab. That said, we do not expect to make significant accommodations for students in unusual situations, unless those students have accommodations evaluated and approved by either the Dean or ARS. In such a situation, you should contact the instructor early with details so we can evaluate whether you should stay in the course. In all cases, we will follow responsible guidelines stipulated by the university, most of which now merely mimic the CDC guidelines. For additional information, see Carolina Together.

Instructional Philosophy: Our future as a species is technological – our very existence will rely increasingly on STEM fields, each of which are highly analytical and will become more so over time. The mathematical content of the course will cover basic numeracy and thinking skills that are required to compete in and understand our technological society. A Makerspace component will enable students to engineer and manufacture physical mechanisms. The computer technology component will educate students about ubiquitous electronic devices, how they work, and will take them *inside* those devices to the programming and electronics. Finally, students will explore and contend with *Mechatronics* in the larger context of society, policy, and discoveries that are already changing our future, for better or worse. Students will learn by interacting and collaborating with the instructor and peers.

New for FA23: The gamechanger in the AI space is ChatGPT and the emergence of LLMs (large language models). This field is changing more rapidly than many such examples of disruptive technology in most of recorded history. Some say that it's the precursor to the Technological Singularity, which up until last year's version of this course was vaguely predicted as "some future speculative event."

Attendance Policy: Absences are frowned upon – not only will important instructional materials be delivered during classroom and lab, but critical announcements may be missed if you do not attend or are late to class or lab. Students *must* contact the instructor *beforehand* if an absence is anticipated, or as soon as is reasonably possible after. If you have to miss a class due to sickness or a legitimate conflict, you should communicate this to the instructor, preferably before the lecture or lab, but as soon as possible under all circumstances. Students are responsible for making up any material that is missed due to absence. Missing lecture and especially lab without an excuse will impact your participation grade. Valid excuses include:

- Severe illness with doctor's note
- Grave family circumstances
- Participating in University-sanctioned events with supporting documentation.
- Travel for jobs or other classes with supporting documentation.

Pre-planned personal trips or family vacations are not valid excuses.

Grades: Students are expected to complete pre-lecture evaluations ("warm-ups") when they are assigned, complete outside assignments ("deliverables"), attend every lecture and lab, actively participate in classroom discussions, take quizzes and exams, and share personal experiences and expertise. A common misconception is that grading is meant to reflect how much you learn in a class, or how much you apply yourself. The Physics Department does not grade in this fashion – grading is based on mastery alone. The reason for the distinction between "mastery" and "how much is learned" is simply that mastery is what can be measured – what you knew or didn't know coming into the class is not something that can be known without extensive pre-testing and unreliable self-reporting. *Everyone in the class, in their own way, is going to learn a great deal, by any measure*.

Grade Evaluation Breakdown: (*subject to change*)

Project:	
Algodoo:	10%
Prototyping:	20%
Final Exam:	5%
Assessments*:	20%
Essays:	20%
Lab Activities:	20%
Participation/Attendance:	5%

Notes:

1. Assessments consist of a variety of quizzes, exam(s), pre-lecture, pre-lab, and post-lab exercises.
2. No scores are dropped and there is no extra credit work.

Course Details: The four main topic areas are summarized below and include the teaching strategy and as well as objectives or outcomes. The actual learning activities will be revealed at course time.

1. **Numeracy and Statistical Reasoning**: The focus is on *mathematical literacy* (the ability to understand and work with numbers). Students will demonstrate competency with units, ratios, scaling laws, probabilities, and data visualization (the relationship between mixes of numbers, for example, by plotting and interpreting graphs). The lecture component will be mixed with group exercises in class and supplemented with instructor feedback and homework assignments. Students will use computers (software) to automate some of these exercises and discover connections that are difficult to discern by eye.

2. **Engineering Design and Rapid Prototyping**: The focus is on mechanism design and manufacture. Students will utilize engineering software to design *kinematic* prototypes, and then manufacture the prototypes using Makerspace facilities. Although "failure" is common, the Makerspace allows such failures to be immediately analyzed and corrected, typically within minutes. This *rapid-manufacture* capability *accelerates* the achievement of design goals and creates a competitive advantage in virtually every modeling endeavor. All students will evolve from a blank slate to designing and building 2-D or 3-D models with wood, paper, acrylic, and/or plastic. Prototyping projects will encourage connections between model building and other parts of the course.

3. **Computer Programming and Technology**: Students will be exposed to the following computing platforms:

    - *Adobe Illustrator: 2-D drawing software to make laser cutter designs*.
    - *Fusion 360: 3-D CAD software to make 3D Printer designs*.
    - *Algodoo*: a unique 2-D physics engine for engineering design.
    - *Arduino* and the *C Programming language*: currently the most popular hobby and robotics microcontroller platform in the world.
    - *Processing*: similar to the Arduino environment, but oriented more toward visualization than hardware interfacing.
    - *Python and TensorFlow*: the dominant python-based player in machine learning
    - (*Optional*) *R*: the dominant player in open-source statistical modeling and neural network visualization.
    - Technologies such as ChatGPT, Stable Diffusion, Roop, etc.

    Working with these platforms will remove much of the mystery of computers and illustrate both the promise and the state-of-the-art limitations of our computerized society. Students that choose STEM majors at UNC will benefit from this early exposure to programming. To complement the use of the Arduino, students will demonstrate basic competency in electronics and wiring. This computer component of the course will largely be in the form of homework and guided inquiry during lab time, with some lecturing by the instructor.

4. **Social Aspects of Mechatronics.** This aspect of the course is simultaneously the most challenging, the most underdeveloped, and possibly the most fascinating – the topics apparently have rare relevance to university courses in general, instead being relegated to an almost infinite variety of on-line discussions in obscure forums, some of which are quite narrow and frequented only by those with questionable motivations. Students will address this aspect of the course from two broad perspectives:

   a) ***Science*** appears in everyday news with increasing frequency, rather than being relegated to peer-reviewed journals. An example in the physical sciences is the emergence of quantum computing. People have difficulty not only making sense of these news items, but also understanding how advances or findings will impact their futures – much of this challenge is based on understanding the capabilities and limitations of science and technology. In some cases, the differentiation boils down to simple *numeracy*, which is a core component of this course. In other cases, technologies cannot even be comprehended or interpreted without a non-trivial grounding in physics and engineering. Students will be faced with simple numeracy tasks that lay the foundation for understanding very complex and futuristic technologies. As an example, students will learn "to count" in order to comprehend and combine probabilities, learn about Boolean logic as used in electronics, and then combine these two to learn about quantum mechanics and quantum computing.

   b) ***Society*** demands an increasing responsibility on the part of scientists to their sponsors, and engagement in the societal and economic impact of science research and development. This is nowhere more relevant than in the field of Mechatronics – an umbrella term that includes but also goes beyond an association with robotics. In particular, students will engage with the underpinnings of *artificial generalized intelligence* (AGI), which some argue will unequivocally lead to the biggest and most uncertain leap in human civilization to date (and which others insist is not possible, or at the very least, will not proceed as predicted). Students will address both the technical aspects and the social implications of many topics that fall under the aegis of AGI, such as self-replication and machine evolution, artificial life and consciousness, the limits of computing, and the prospect of simulated reality.

Important Dates during the Semester. In lieu of a full course schedule (for now), the following dates are important milestones in the course:

- Aug 21: FDOC
- Aug 21: First lab.
- Sep 04: Labor Day (no class or lab)
- Sep 25: 2nd Wellness Day (no class or lab)
- Nov 22: Thanksgiving Break
- Dec 06: LDOC
- Dec 14: Final Exam (8a)

Welcome to the course! Watch for announcements in e-mail that clarify many of these topics.

Honor Code. The Honor code and the Campus Code, embodying the ideals of academic honesty, integrity, and responsible citizenship, have for over 100 years governed the performance of all academic work and student conduct at the University. Academic dishonesty in any form is unacceptable, because any breach in academic integrity, however small, strikes destructively at the University's life and work. If you have any questions about the Honor Code, please consult with someone in the Office of the Student Attorney General or the Office of the Dean of Students. Any issues that students encounter related to fairness or inappropriate conduct should be brought to the immediate attention of an instructor.

Acceptance by a student of enrollment in the University presupposes a commitment to the principles embodied in these codes and a respect for this significant University tradition. Your participation in this course is with the expectation that your work will be completed in full observance of the UNC Honor Code, which can be found at http://studentconduct.unc.edu/students/rights-responsibilites.

*We aggressively pursue cheating cases with the Honor Court. You will do well to inform yourself of the procedure: as professors, we merely need to see what we consider to be **evidence** of cheating, and we will submit your name to the Honor Court – **we need no proof whatsoever, and we are not bound by the limits of the semester schedule**. In turn, you will find your assigned course grade changed to an NG, and you will be forced to endure the embarrassing and damaging process of appearing in honor court to answer.*

In 2019, 2 students from this very first year seminar went on to PHYS118 in SP20 and were caught in honor code violations at that time. It pains me greatly to have a personal connection to such students and then be the one to open them to prosecution in ways that will tarnish their reputations forever and possibly impact their ability to even graduate.

Ask your peers about the experience: it is not worth it!

Accessibility Resources. The university facilitates the implementation of reasonable accommodations, including resources and services, for students with disabilities, chronic medical conditions, a temporary disability, or pregnancy complications resulting in barriers to fully accessing University courses, programs, and activities. Accommodations are determined through the Office of Accessibility Resources and Service (ARS) for individuals with documented qualifying disabilities in accordance with applicable state and federal laws. See the ARS Website for contact information: https://ars.unc.edu or email ars@unc.edu.

Counseling and Psychological Services. PHYS55 can be a challenging course – it may require more time than expected. If you are feeling anxious or overwhelmed, we strongly encourage you to contact your instructor to discuss your concerns. In addition, the university CAPS system is committed to addressing the mental health needs of the student body through timely access to consultation and connection to clinically appropriate services, whether for short or long-term needs. The Heels Care Network website (https://care.unc.edu) is a place to access the many mental resources at Carolina. CAPS is the primary mental health provider for students, offering timely access to consultation and connection to clinically appropriate services. Go to their website https://caps.unc.edu/ or visit their facilities on the third floor of the Campus Health building for an initial evaluation to learn more.

Title IX Resources. Any student who is impacted by discrimination, harassment, interpersonal (relationship) violence, sexual violence, sexual exploitation, or stalking is encouraged to seek resources on campus or in the community. Reports can be made online to the EOC at https://eoc.unc.edu/report-an-incident/. Please contact the University's Title IX Coordinator (titleixcoordinator@unc.edu), Report and Response Coordinators in the Equal Opportunity and Compliance Office (reportandresponse@unc.edu), Counseling and Psychological Services (confidential), or the Gender Violence Services Coordinators (gvsc@unc.edu; confidential) to discuss your specific needs. Additional resources are available at safe.unc.edu.