SYLLABUS: Physics First Year Seminar – Fall 2024 [0th Draft]

Introduction to Mechatronics

Instructor of Record: Dr. Stefan Jeglinski (Dr J) *office*: Phillips 174
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Lecture: Phillips 247 MW 10:10a–11:25
Lab: Phillips 267 M (1:30p or 3:30p)
Office Hours: TBD
Teaching Asst: TBD

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.FA24
- Makerspace Access – see Canvas announcement posted and also early lectures.

Prerequisites: High-school math/reading/writing skills, and very strong interest in technology.

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 five areas:

- *Numerical Reasoning* (mathematical content)
- *Engineering Design and Rapid Prototyping/Manufacturing* (Makerspace)
- *Computer Technology* (Programming and Electronics)
- *Artificial Intelligence* (history and use)
- *Social Aspects of Mechatronics* (aka "*please welcome our benevolent robot overlords*")

In some cases, our topics will be covered in parallel because of the way they are linked. Although not necessarily obviously related to one another, most topics will be introduced early so that you may evaluate whether to stay in the course, but many details will be deferred to the bulk 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 our 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 find cross-disciplinary opportunities 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 Euler diagram on Canvas home page). The term *Mechatronics* 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); it seems to be most commonly thought of as a successor or sibling term for *robotics*, but this is too limiting, as we'll also explore artificial intelligence and a *social* component in the course, two subjects that we will consider in forward-thinking and provocative ways. Regardless of what the term means, you'll be learning topics that are quite recognizable to those with actual degrees in *Mechatronics* but will also be relevant to you regardless of your field.

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.
- Understand the basic quantities of voltage, current, and impedance.
- Build elementary electronic circuits.
- Train and certify on tools in the Makerspace (typically laser cutters and 3D printers).
- Design a kinematic object in simulation software.
- Build a working implementation of your kinematic object using Makerspace resources.
- Explain the landscape of AI: history, present, and possible future.
- Build simple neural networks in software to perform classification and deep learning.
- Leverage new AI tools such as ChatGPT and Stable Diffusion.
- Analyze and evaluate the possibility that your existence is merely a computer simulation.
- Term Paper: Choose a topic of impact to society and analyze/evaluate your place within its boundaries, including the definition of those boundaries. Topics are limited to: the computer-brain interface; the surveillance state; truth and fiction; love and death; the future of employment; the technological singularity; the role and impact of AI in current human evolution.
- And probably even more!

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 each lab is listed as 2 hours, they'll not typically be that long; in addition, some labs won't look like traditional labs – instead they'll 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. The TA will assist in all aspects of the course. 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 difficult 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 has now been operating "normally" for a couple years; however, impacts from the pandemic are still evident. You're 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. We do not expect to make significant accommodations for students in unusual situations that are outside of the university guidelines, unless those students have accommodations evaluated and approved by either the Dean or ARS. 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 and kinematics 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. The gamechanger in the AI space is the emergence of LLMs (large language models, e.g., ChatGPT). This field is changing more rapidly than most if not all historical examples of disruptive technology over most of recorded history. Some say that our current state of affairs is the precursor to the *Technological Singularity*, which up until only recently was vaguely predicted as "some future speculative event." Your instructor believes that the future is now much closer than we thought and is much less speculative.

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 don't attend or are late to class or lab. Students must contact the instructor before lectures or labs if an absence is anticipated, or as soon as is reasonably possible after. Students are responsible for making up any material that is missed due to absence, subject to late penalties. Missing lecture and especially lab without an excuse will impact your participation grade. Valid excuses will waive late penalties and include:

- Severe illness with doctor's note or 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, 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 (knowledge or skill that allows you to demonstrate understanding of a subject). 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 include quizzes, exam(s), pre-lecture, pre-lab, and post-lab exercises.
2. No scores are dropped and there is no extra credit work.
3. Makeup work will be assessed late penalties, which are waived only for UAAs.
4. UAA = University-Approved Absence.

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

1. **Analog and Digital Literacy**: Computers are fundamentally *digital* devices (discrete signals of value one and zero only), but the universe we live in appears to be *analog* (divisible signals between zero and one) except for the quantum realm. Our focus will be on *signal literacy* (the ability to see and understand the expression of information, what it represents in the physical world, how it changes, and how it's transferred). Much of what we'll learn here will be delivered in lecture with small assessments that will carry over to electronics, smartphone, and microcontroller experiments. Students will use computers (software) to visualize connections that are difficult to discern by eye. *If you consider yourself math-phobic, open a dialog with the instructor early in the course.*

2. **Engineering Design and Rapid Prototyping**: Our engineering focus is on mechanism design and manufacture. Students will utilize 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 move 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: 2D drawing software for laser cutter designs*.
    - *Fusion 360: CAD software for 3D Printer designs*.
    - *Algodoo*: a unique 2D physics engine for engineering simulation.
    - *Arduino* and the *C Programming language*: currently the most popular hobby and robotics microcontroller platform on this planet.
    - *Processing*: similar to the Arduino environment but oriented toward visualization rather than hardware interfacing.
    - *Python*: the dominant python-based player in machine learning.
    - *Large Language Models (LLM)*: the biggest revolution since we don't know when…
    - Pending*:* Open-source AI image generation.
    - Pending*:* Open-source deep fake audio/video generation.

    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 and LLMs. Much of the digital and analog literacy course component will dovetail here. 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. **Artificial Intelligence**: Our AI focus is on the history, philosophy, definition, mechanism, future, and effects of AI. We will focus specifically on neural networks, machine learning, and possibly quantum computing if time allows. The obvious contender for primary study is the impact of the LLM (e.g., ChatGPT). Much of our time will be spent in lecture, but a variety of lab explorations using Python are planned. Assessments on this topic will be numerous and will include essay writing.

5. **Social Mechatronics.** This aspect of the course is simultaneously the most challenging and possibly the most fascinating – the subject is rarely addressed in university courses and until recently was relegated to a variety of on-line forum discussions with narrow motivations. The advent of the LLM has single-handedly transformed this space into a landscape of fantastic speculation and wild claims. We will attempt to 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. 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, our challenge boils down to simple digital and analog numeracy, which is a core component of this course. For example, we will explore the basic analog nature of a neural network and see how it's implemented with digital computers. This path will lead us to a better understanding of the *Large Language Model* of computer and data science. In other cases, technologies cannot be comprehended, much less interpreted, without a non-trivial grounding in physics and engineering. A good example of such is *quantum computing*. To even begin to comprehend this topic, we'll have to learn about "counting" to comprehend and combine probabilities, Boolean logic as used in classical electronics, and a lay approach to quantum mechanics. This path opens the possibility of comprehending the quantum computer.

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, used as an umbrella term that includes but also goes beyond an association with robotics. Students will engage with the underpinnings of *artificial generalized intelligence* (AGI), which some argue will unequivocally lead (or has now led) to the biggest and most uncertain leap in human civilization to date, with fewer and fewer insisting that the jump 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. Our studies will incorporate a variety of media from fiction and non-fiction writings, current events, video resources (including Hollywood), essay works from both modern and older authors, and contributions from both you and the instructor's life experiences to date.

Important Dates during the FA24 Semester. the following dates are important milestones in the course for **FA24**:

- Aug 19: FDOC
- Aug 19: First lab.
- Sep 02: Labor Day (no class or lab)
- Sep 23: 2nd Wellness Day (no class or lab)
- Nov 27: last lecture before break
- Nov 28–29: Thanksgiving Break
- Dec 04: LDOC
- Dec 10: Final Exam (8a)

The course schedule from **FA23** is shown on the next page. It should not be construed as our course schedule or topic list for **FA24** (obviously we are not anticipating class cancellations).

FA23 Course Schedule

Lecture 01 Aug 21: Course Intro
Lecture 02 Aug 23: Processing I
Lecture 03 Aug 28: Mechanism and Algodoo
Lecture 04 Aug 30: canceled
Lecture 05 Sep 06: canceled
Lecture 06 Sep 11: Processing II
Lecture 07 Sep 13: Illustrator Tutorial
Lecture 08 Sep 18: Mechanism – Project Details and Deadlines
Lecture 09 Sep 20: Chinese Room
Lecture 10 Sep 27: Are We All Dead?
Lecture 11 Oct 02: Essay Details and Deadlines
Lecture 12 Oct 04: Intro to AI 1
Lecture 13 Oct 09: phyphox for motion measurements
Lecture 14 Oct 11: Computer Hardware/Software
Lecture 15 Oct 16: Arduino I – Introduction
Lecture 16 Oct 18: Arduino II – Code Libraries and Number Systems
Lecture 17 Oct 23: Number Systems II and Arduino PWM
Lecture 18 Oct 25: Ohm's and Kirchhoff's Laws; Arduino PWM
Lecture 19 Oct 30: Voltage Division and Arduino Analog Input
Lecture 20 Nov 01: Library, IDST, Text↔Image AI
Lecture 21 Nov 06: Neural Networks I
Lecture 22 Nov 08: Neural Networks II – Machine + Deep Learning
Lecture 23 Nov 13: Neural Networks III – Deep Learning and Classification
Lecture 24 Nov 15: Neural Network Wrap-up
Lecture 25&26 Nov 20&27: Are We All (Still) Dead I&II?
Lecture 27 Nov 29: ChatGPT and LLMs
Lecture 28 Dec 04: Quantum Mechanics
Lecture 29 Dec 06 (LDOC!): Quantum Computing

Lab 01 Aug 21: Software Downloads
Lab 02 Aug 28: canceled
Lab 03 Sep 11: Algodoo
Lab 04 Sep 18: Illustrator Workshop
Lab 05 Oct 02: Prototyping Mechanisms
Lab 05 Oct 02: TA Support
Lab 06 Oct 09: phyphox
Lab 07 Oct 16: Arduino I – Introductory Lab
Lab 08 Oct 23: Arduino II – Command and Control
Lab 09 Oct 30: Analog Electronics + Arduino
Lab 10 Nov 06: Text-to-Image
Lab 11 Nov 13: Stable Diffusion and Neural Networks

Lab 12 Nov 20: Makerspace
Lab 13 Nov 27: Makerspace
Lab 14 Dec 04: Makerspace

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 or TA 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.