PHYS 524 - Survey of Instrumentation and Laboratory Techniques

Course description
This course will introduce students to a broader spectrum of devices than they can be expected to encounter in their Physics 523 projects. The goal of the course is to familiarize students with some of the techniques available to them when defining and proposing a technical project in an unfamiliar domain. There will be two 50 minute classes each week, split into a discussion of basic principles and a simple hands-on laboratory exercise. The list of topics—which is not intended to be exhaustive—will evolve, according to the interests of the class and instructors. Material will be clustered into units of varying duration, as indicated below. The lists of suggested readings and references are advisory; a large amount of material of excellent quality is now available on the worldwide web, particularly on the sites of university courses addressing the topics of each unit. There are no formal prerequisites other than prior completion of a rigorous undergraduate major (or minor) in physics, astronomy, or a related field.

Credit and grading
Students must register for this course in the fall semester for a total of 2 credit hours. Grading is by letter.

Learning objectives
As a result of completing this course, students will be able to

- Identify devices, tool sets, and analysis techniques that might be relevant to execution of technical projects.
- Understand the relative merits and drawbacks of diverse approaches to accomplishing a particular end in a technical setting.
- Propose the most efficient (tool-dependent) sequencing of activities in a technical project.

Syllabus: topics covered

Unit 1: Integrated development environments (3 weeks)

- Arduino C++ programming environment;
- Anaconda Scientific Python;
- EAGLE schematic capture and printed circuit board layout facility.

Unit 2: Inter-device communication protocols and embedded systems (1 week)

- I2C, SPI, UART serial.

Unit 3: Microcontroller-interfaced sensors (4 weeks)

- Motion: acceleration, rotation, orientation;
- Gas and atmospheric properties: alcohol, methane, humidity, barometric pressure, volatile organics, airborne particulates;
- Proximity and location;
- Thermometry;
- Voltage;
- IR, visible, and UV illumination;
- Sound and acoustics.

Unit 4: Rapid prototyping (1 week)

- 3D structure modeling: TinkerCad, Cura;
- Additive layer manufacturing; single- and dual-nozzle methods.

Unit 5: Cooling and thermal management (2 weeks)

- Peltier effect thermoelectric cooling;
- Insulation;
- Conduction and convection.

Unit 6: Testing, debugging, and quality assurance (1 week)

Unit 7: Modeling (2 weeks)

- Static structures and finite element analysis;
- Vibration analysis;
- Monte Carlo techniques.

Readings and other sources

Unit 1 reading and reference material:

- *Arduino project hub tutorials,* https://www.arduino.cc/en/Tutorial/;
- *The Python Tutorial,* https://docs.python.org/3/tutorial/index.html ;
- *Using EAGLE: Schematic,* https://learn.sparkfun.com/tutorials/using-eagle-schematic;
- *Using EAGLE: Board Layout,* https://learn.sparkfun.com/tutorials/using-eagle-board-layout.

Unit 2 reading and reference material:

- *I2C,* https://learn.sparkfun.com/tutorials/i2c;
- *Serial Peripheral Interface (SPI),* https://learn.sparkfun.com/tutorials/serial-peripheral-interface-spi;
- *Serial Communication,* https://learn.sparkfun.com/tutorials/serial-communication/all.

Unit 3 reading and reference material:

- See the various tutorials on the web sites of the sensors' manufacturers. For example, https://learn.adafruit.com/adafruit-bme680-humidity-temperature-barometic-pressure-voc-gas;
- *Fundamentals of Acoustics 4th ed.,* L.E. Kinsler et al., John Wiley & Sons, Inc. (2000).

Unit 4 reading and reference material:

- *Place IT!,* https://www.tinkercad.com/;
- *How to use different softwares,* https://ultimaker.com/en/resources/21896-how-to-use-different-softwares.

Unit 5 reading and reference material:

- *Thermal Management Handbook,* Maxim Integrated (2014), available online.

Unit 6 reading and reference material:

- *Model Checking,* E.M. Clarke, Jr. et al., The MIT Press (1999);

Principles and Practices of Quality Assurance, Ann Gravelis, SAGE Publications (2016).

Unit 7 reading and reference material:

- T*he Finite Element Method: Linear Static and Dynamic Finite Element Analysis,* Thomas J.R. Hughes, Dover (2000);
- *Fundamentals of Vibration Analysis,* Nils O. Myklestad, Dover (2018);
- *Simulation and the Monte Carlo Method,* R.Y. Rubinstein and D.P. Kroese, Wiley (2017).