

Physics 192M -- Introduction to Measurement using the Arduino
a one-credit course recommended for Physics majors
Syllabus for Spring 2021

Location: Zoom, <https://umass-amherst.zoom.us/j/91039830028>. Section times are listed on SPIRE (and note that 01 and 03 start at 1:25, not 1:30.). Please join Zoom 5 minutes before your class starts.

Synchronous-required: attendance is needed to get feedback from the instructors.

Instructor: Prof. Tony Dinsmore, Hasbrouck 404, E-mail: dinsmore@umass.edu

Teach assistant: TBA

Number of course credits: 1 credit. I anticipate about 2-3 h/week of time outside class on average.

Learning objectives: Key skills to be developed: (i) Posing a curiosity-driven question in a constructive way; (ii) designing, making, and trouble-shooting an apparatus to measure a physical quantity; (iii) facility with the hardware-software interface; and (iv) confidence in completing a technical task independently. By the end of the course, students will have defined their own question, set up a device to collect data, and answered the question. The course also provides a first experience (for many) in creating a logical sequence of steps to carry out a task, in preparation for programming. No technical experience is needed.

Required materials: The Arduino is a powerful and simple-to-use microcontroller, a powerful interface between your computer and a huge variety of detection and measurement devices. Arduinos are simple enough to get started with even if you have zero experience, and are powerful enough to use in many settings (*e.g.*, in my research lab.)

You will need to purchase your own Arduino (Uno R3 or similar).

Please see the end of this document for many details on purchasing. You will also need a variety of smaller parts. I estimate the total cost to be about \$20 for the Arduino and \$15-20 for the remaining objects. At your option, you may wish to purchase another detector later in the semester; typical costs vary from \$5 to (rarely) \$50. Alternatively, the instructors can lend you these parts. If you will be on campus, this will be easy to do. If you will not be on campus (but are in the US), then we will rely on mail so there might be delays. If you will be overseas, I will not be able to mail you things.

There is no textbook for this class.



What to bring to class: a laptop or desktop computer with a spare USB port works best. A notebook or tablet are needed each day for writing notes (a keyboard is not suitable for this). From time to time, students may wish to purchase small items for their devices as described above.

Expectations in class: Classes last 2h. There will be time for a short break partway through. On a typical day, one or both of the instructors will give a short lesson or demonstration. We will also review your work on the previous HW with you (*via* screen-sharing on Zoom), so be sure it is done on time. The rest of the class time will typically be for you to work on a mini-project, or (later in the semester) working on your own project, with help from instructors or peers. You will be expected to take notes and draw diagrams in class, and the instructors might ask to see them at any time.

Course Webpage: The course webpage is on MOODLE (<https://moodle.umass.edu>).

Course email list: We will use the Spire course email list for occasional announcements. This list uses your UMass email account, which UMass considers an official means of communication. Please do not use any other email accounts in your course-related correspondence.

Accommodation Statement: The University of Massachusetts Amherst is committed to providing an equal educational opportunity for all students. If you have a documented physical, psychological, or learning disability on file with Disability Services (DS), you may be eligible for reasonable

academic accommodations to help you succeed in this course. If you have a documented disability that requires an accommodation, please notify the instructor within the first two weeks of the semester so that we may make appropriate arrangements.

Academic Honesty Statement: Since the integrity of the academic enterprise of any institution of higher education requires honesty in scholarship and research, academic honesty is required of all students at the University of Massachusetts Amherst. Academic dishonesty is prohibited in all programs of the University. Academic dishonesty includes but is not limited to: cheating, fabrication, plagiarism, and facilitating dishonesty. Appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Instructors should take reasonable steps to address academic misconduct. Any person who has reason to believe that a student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor as soon as possible. Instances of academic dishonesty not related to a specific course should be brought to the attention of the appropriate department Head or Chair. Since students are expected to be familiar with this policy and the commonly accepted standards of academic integrity, ignorance of such standards is not normally sufficient evidence of lack of intent (http://www.umass.edu/dean_students/codeofconduct/acadhonesty/).

Specifically in this course, each student will work on his or her own project most of the time. Students are completely free (even encouraged!) to get help from peers, or from any source at all. In that sense, there is no “cheating” in this class as long as you cite your sources. Examples of citing sources include “I talked to [...] in class” or “I found a diagram at www.blah.org.” You must cite your source in all homeworks, reports, and written computer codes.

Requirements and grades:

- **Attendance at the scheduled class time is required** (“synchronous-required”). For each missed class, the final grade will be reduced by a penalty (*i.e.*, by 5 points) unless there is a medical reason (with note) or pre-arranged excuse. **Participation** overall is worth 10%. This includes attending, being ready to start work promptly at the start of class, being active in class, taking notes in class, and contributing in a positive way to the class environment.
- **Homeworks** will be graded and are worth 30% of your grade in total. The expected time for assignments is 2-3 hours per week. In many cases, these will be short electronic summaries of what you did and a plan or code or procedure that you developed.
- **Projects.** The final project will be worth 40% of the grade. There are two mini-projects during the semester, worth a total of 20%.
- **Grades** will be based on your efforts and progress made from where you started.
 - The grade of B means that the student has done all of the required elements and demonstrates a satisfactory understanding. The assignments were intelligible to anyone (non-expert peers) other than the author.
 - If the assignments show a high level of creativity and/or critical thinking, the grade will be higher.
 - Grades below B are assigned if parts of the experiment or questions are done incorrectly, or if the report is poorly organized or otherwise hard to understand. D is given if the student misunderstood the major goal of the lab (which I hope will not happen).

In-class (on Zoom) expectations:

- 1) We prefer that you keep your camera turned on, though it is not required. This class will work best with interactions, and cameras can help.
- 2) Some parts of each class might be recorded (*e.g.*, lessons or demos).
- 3) Do not comment on someone else’s project without first being asked. We can all help one another, but let us first wait to be asked. We will all have a chance to talk about our projects at some point.
- 4) If you want to borrow something, ask the instructor and we will try to make that happen.
- 5) Do not eat or drink in class. (We know you are at home, but food and drink mix badly with keyboards and other electronics.)

- 6) Enjoy it. Making things work is a lot of fun and empowering (especially when you have to struggle to get there).

Other resources: 3D printing at UMass: <https://www.library.umass.edu/services/computers/3d-printing/>
For purchasing materials: Adafruit: <https://www.adafruit.com/>

Required materials: where to get them.

1) The Arduino (approx. \$20)

There are many arduino boards that you can use. They have similar speed but vary somewhat in memory (*i.e.*, data storage capacity), in the number of pins (which is not likely to be an issue in this class) and in physical size. They also vary in their availability; this varies and I find it's not easy to predict.

Some general notes: if offered the choice, get the “headers,” which make it a lot easier to plug in wires. Pay attention to the USB cable; you need one. All of the arduinos listed below except the Metro use the USB AB type.

I do not recommend the kits that come with a lot of sensors. The Elegoo and sparkfun ones have very low quality sensors, not worth the money (and they can cause a lot of frustration). Kits that include breadboards, voltmeters, AC adapters can be good – these are all useful.

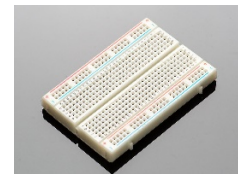
Here are some options – you only need one!

- From Amazon: ELEGOO UNO R3 Board ATmega328P ATMEGA16U2 (\$14), a clone of the Arduino Uno. (Elegoo *sensors* are often of low quality but I've used many of their uno boards and never had any problems.)
- Arduino Uno Rev3 (\$23), <https://store.arduino.cc/usa/arduino-uno-rev3> . Check the availability and shipping time.
- Arduino Mega 2560 R3 (\$40), <https://www.adafruit.com/product/191> (out of stock in Dec 2020, but it may come back) Also try <https://store.arduino.cc/usa/mega-2560-r3>. or Amazon (\$40). Compared to the Uno or the Metro 328, the Mega has more memory. This can be useful for some projects but is not essential and there are other ways to store data than in on-board memory.
- Adafruit Metro 328 (\$17.50) a clone of the Adafruit Uno. <https://www.adafruit.com/product/50>. This one has a small-format micro USB port on the board (the kind used for charging Samsung and many other devices). The standard AB type USB cable won't work.
- Arduino UNO WiFi REV2 (\$40). Amazon . This is the Uno with a few extra capabilities including wifi and Bluetooth. I have not used these, but other students have. They are not required.
- Arduino student kit (\$59) includes voltmeter – a nice thing to have. <https://store.arduino.cc/usa/student-kit> (check availability and shipping time)

Software: Arduino IDE 1.8.13 (free), <https://www.arduino.cc/en/software/> (Select “Windows” if you are using a PC, not “Windows App”) I recommend using the default settings. If you have a chromebook or tablet that cannot run the IDE, then you can use their web-based IDE.

2) Breadboard (see picture at right): Adafruit, half-size (\$5).

<https://www.adafruit.com/product/64> Also available at Amazon.



3) Jumper wires: get male/male type. E.g., \$4 for a pack of 40

(<https://www.adafruit.com/product/758>). Also available from Amazon, of course. You can also strip your own wires if you have a wirestripper, but these jumper wires have good connectors that make them better for repeated use.

4) Sensors and other small electronic components: It's best if you purchase these with the other items.

Otherwise I maybe able to lend/mail you these parts; see “Required materials” on page 1.

1. TMP36 - Analog Temperature sensor - TMP36 (\$1.50 each; I suggest 2 in case one breaks). <https://www.adafruit.com/product/165> (Less expensive and more reliable than Amazon)
2. Phototransistor light sensor (\$0.95) <https://www.adafruit.com/product/2831>. Also available at Digi-key, <https://www.digikey.com/en/products/detail/adafruit-industries-llc/2831/8323990?s=N4lgjCBcoLQdIDGUBmBDANgZwKYBoQB7KAbXAFYAmADhAF0CAHAFyhBAF8ODLSRGAFoWbCATmgB2WAJZYRo%2BhyA>

3. Resistors: A couple of different values of resistance.
 - a. At least 3 each of these: roughly 1 kiloOhm ($1\text{ k}\Omega$), and roughly $10\text{ k}\Omega$. It's fine if your resistors differ by up to a factor of 2. In many applications, it does not matter too much what the resistance value is as long as we know what it is.
 - b. One possibility: Elegoo 17 Values 1% Resistor Kit Assortment, 0 Ohm-1M Ohm (Pack of 525) (\$13 on Amazon). It's more than we will need, but useful if you think you will work with electronics beyond this class.
4. Light-emitting diodes (LEDs). Get a few of various colors. Get the kind that have two wires (two electrodes, two prongs). Example: <https://www.adafruit.com/product/4203> (\$5). Don't get the 3-electrode RGB ones (or, at least, you can but also get some of the regular 2-electrode kind). (Adafruit has lots of LEDs that don't have wires attached, in which case you would have to solder. That is not what you want.)

How-to videos and other resources:

Sebastian Lague on Youtube. <https://www.youtube.com/watch?v=QZwneRb-zqA> "Exploring How Computers Work" The first part is good, but you need not go too far into the method of adding.
How Do Computers Remember? <https://www.youtube.com/watch?v=I0-izyq6q5s>