# Wellesley College CS115/PHYS115

# Robotic Design Studio

**January, 2009**

## Course Information

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**Location:** SCI L024. (Phone in SCI L024: 283-3346.)

**Meeting Times:** 1pm – 5pm, Tue. – Fri., Jan. 6 – 23 **plus Mon. Jan 26**. A few notes:

The robot lab (SCI L024) will be accessible around the clock, and we encourage you to tinker there outside the "official" hours of the class.

There is no official meeting on Mondays (except Mon. Jan 26), but you are welcome to use the robot lab on these days to work on design challenges and your final project.

All students in the class are expected to participate in the Robot Exhibition from 4:30 – 6pm on Mon., Jan. 26 and the cleanup party immediately following (6pm – 8pm).

There are no official class meetings on Tue. Jan 27 and Wed. Jan 28, but you can use these days to finish your design journals and web pages. Both are due at 5pm on Wed. Jan 28.

**Course Web Sites:** There is a web site with information pertaining specifically to this year's version of the course at:

http://cs.wellesley.edu/~rds/

For example, information about your fellow students, your course account, and

creating a web page for your robot can be found at this site.

## Course Overview

In this intensive introductory course, you will have an opportunity to design and assemble robots out of LEGO parts, sensors, motors, and miniature computers (PicoCrickets and Handy Boards), and then program your creations to do your bidding. We start by learning some fundamental robotics skills in the context of playing with PicoCrickets and studying/modifying a simple robot known as SciBorg. Then, working in small teams, you will design and build your own robot. The course culminates in a Robot Exhibition on Monday, January 26, from 4:30 – 6pm, in which you will show off your robots to the Wellesley community. This is a festive event that is attended by students, faculty, staff, and their families.

This course is rooted in *constructionism*, whose main tenet is that people learn best when actively engaged in hands-on projects that are personally meaningful and enjoyable.

Robotic projects tie together aspects of a surprisingly wide range of disciplines, including computer science, physics, math, biology, psychology, engineering, and art. Here are some of the concepts and skills you can expect to learn in this course:

- robot = sensors + controller + actuators.
- simple programming: robot commands, control flow (sequencing, conditionals, loops, procedure calls, concurrency), procedural abstraction.
- basic electronics: voltage, current, power, motors, sensors.
- fundamental mechanics: building robust structures, friction, power transmission, gearing, LEGO design clichés.
- animal and machine behavior, with ties to biological, cognitive, and social science.
- simple web page design.

You will also get hands-on exposure to some of the "big ideas" of engineering:

- hypothesis testing and debugging.
- making iterative improvements.

- working with *systems* (design in multiple domains, subpart interaction).
- designing *behaviors* (sophisticated behaviors can arise from relatively simple rules).
- working in the real (noisy, messy, unpredictable *etc*.) world.
- divide-and-conquer strategies for problem solving.
- modularity and abstraction.
- feedback and control.
- paying attention to *aesthetics*.
- the value of simplicity and robustness.

We believe that this kind of exposure to the important ideas of engineering should be a critical part of today's liberal arts education. A grounding in these ideas is necessary in order to understand our times and our culture. The best way to become fluent with these ideas is to become a designer and a builder. In today's liberal arts curriculum there is a relative absence of design and building for students of science or technology. In contrast, there tend to be lots of design experiences for artists and humanities students.

## Prerequisites

The only prerequisite for this course is a willingness to learn about, and have fun with, robots. The course is not just for scientists – all creative people are encouraged to participate!

## Credit

One-half (0.5) units of credit will be awarded for successful completion of this course. This credit counts toward the Natural and Physical Sciences (NPS) distribution. As of this writing, Robotic Design Studio does **not** count as a laboratory course.

## Reading Materials

We will post several articles, manuals, and notes during the course, and will post suggested reading where appropriate. All handouts will be made available from the course web page.

## Homework

In addition to working on design challenges and other hands-on activities in during class time, you will be asked to complete several challenge problems as homework assignments. Assignments will typically involve reflecting and expanding on work done in class, thinking about points raised in reading, or documenting stages in the design and construction of your robot.

## Individual Design Journal

Each student is required to maintain an individual design journal to document her journey through the course. The design journal is a single artifact that should contain all of the following:

- lecture notes taken during class.
- answers to homework assignments.
- documentation of your solutions to the design challenges, including sketches, code, and explanation of strategies.
- documentation detailing the design and construction of your final project, including words, sketches, and code.
- other thoughts/observations/sketches inspired by the hands-on activities, reading, *etc*.

We encourage you use a bound notebook such as a composition notebook or a spiral notebook for your design journal. We recommend that you do **not** use a loose-leaf binder for your design notebook. You should date each entry to the journal, and tape or glue loose materials (such as code listings) to pages into the journal.

You should use your design journals as a kind of diary in which you write down/sketch all thoughts, designs, etc. you have that are relevant to the robot course. If you have an idea, don't wait until later to jot it down; jot something down right away and then maybe flesh it out more later. Don't be obsessed with making the journals excessively neat, since this may reduce your probability of jotting things down. On the other hand, do try to make the writing legible.

We will examine your design journals in class at regular intervals throughout the course to check off your progress on challenges and to provide feedback on your robot designs. At the end of the course, you will submit your final design journal,

which should contain a detailed description of the process by which your final project took shape. The write-up of your final project design in your journal should be something that has evolved on a day-to-day basis, and not something you compose in a mad dash at the end of the course!

## Group Robot Project

The second half of the course is devoted to the robot project, in which you will work in a team of two or three people to design, build, exhibit, and document a robot. The project is open-ended; you should brainstorm with your teammates about projects that are fun, exciting, and challenging, but at the same time realistic. To give you a sense of what's possible, you should browse the web pages describing projects from previous incarnations of the course (1996 – 2007). These are accessible from:

`http://cs.wellesley.edu/~rds/museum.html`

When forming teams for your project, it is wise to choose teammates with complementary strengths. For example, it's good to have members with programming experience, mechanical know-how, artistic sense, and good writing and presentation skills.

As part of your robot project, you will be expected to do the following:

*As a group:*

- *Develop* a preliminary design for your robot, including sketches, descriptions of behavior, and perhaps some high-level pseudo-code. All groups will give a brief presentation of their robot designs in class on Tue., Jan 16. As part of the presentation, you should write up and distribute a preliminary design document to the class.

- *Build* the robot you have designed. This is an iterative process in which you will build, program, test, see what works and what doesn't, and make changes to the design. You repeat this process until you are done (rare) or you run out of time (more likely).

- *Document* your robot with pictures, video, text, and code in a World-Wide Web page that will forever remain a part of the Robotic Design Studio electronic museum. All members of the group are expected to contribute to the process of documenting your project. (For example, you should *not* rely on a single person with web design experience to do all the work!)

- *Exhibit* the robot you have built at the Robot Exhibition on January 26, 2009.

*As an individual:*

- *Document* the design and implementation of the robot in your design journal. In particular you should try to highlight the contributions you individually made to the project.

## Grades

Rather than focusing on a grade, we hope that you will focus on learning a lot and having fun while building creative robots. After all, students during two previous Wintersessions ('96 and '97) built *very* impressive projects without receiving any credit at all!

Your grade for the course will be determined by three factors:

1. Your design journal, which includes your homework assignments and your individual documentation for your group final project.

2. Your group robot project, including the web page documenting your group's robot.

3. Your class preparedness and participation. It is expected that you will attend all classes.

In keeping with the College's grading policy, we expect that the average grade in this course will be no higher than a B+.

We hope that the grades will not stifle your creativity or otherwise detract from your experience in this course. If you think they might, we suggest you consider taking this course on a credit/non-credit basis.

## Collaboration Policy

We strongly encourage you to get to know all of your classmates and to collaborate extensively with them. Because of the interdisciplinary nature of the course, it is likely that you will be strong in some areas but weak in others. Please share your strengths with others, and don't hesitate to ask others for help in the areas in which you feel that you are weak.

In your design journal, all observations, reflections, and documentation should be in your own words. You may reference the ideas of your classmates, but should

give them proper attribution in your writing.

## Laboratory and Computing Environment

Classes will be held in Science Center room L024. This room will be referred to as the "Wintersession Robotics Laboratory". The room will be unlocked during the normal weekday hours of the Science Center. However, you will have access to the room 24 hours a day, 7 days a week during Wintersession; details will be announced in class. Science Center policy requires that every student have a "buddy" when working after hours.

The lab is equipped with 12 PC computers. If you have a PC or Mac OS X laptop you can use it for this class if you like. We will primarily use the following applications during the course:

- *Handy Logo* and *PicoBlocks* : program development environments for the Handy Boards and Crickets.
- *WinSCP* : a Windows-based secure file transfer program for uploading files to and downloading files from the net. (The corresponding Macintosh program is *Fetch*.)
- *Macromedia DreamWeaver* : a web-page builder.
- *Adobe Photoshop and Macromedia Fireworks* : image manipulation programs for preparing JPEG photos shot with the digital camera.

We also encourage you to document your robot's progress by recording video clips.

Each student should back up her daily work onto memory sticks and/or their FirstClass accounts.

Each final project team will be given a computer account on the CS file server where all project files (code, web pages, pictures, video) should be stored. Details on this account and accessing the CS file sever via WinSCP will be provided in class; some documentation is also provided on the course web page.

## FirstClass Conference

The `CS/PHYS115-W09` FirstClass conference is a place for members of the class to communicate with each other.

## Course Schedule

There are thirteen four-hour class meetings, which naturally split into two categories:

1. During the first seven class meetings, we will teach you the basics of robot design. These meetings will consist of lectures interleaved with numerous hands-on activities in which you will modify an existing robot or build a simple robot from scratch.

2. During the last six class meetings, you will work with your teammates on the design and implementation of a robot for your final project.

Below is a tentative schedule for the class:

### Tuesday, January 6 (Class 1) *Introduction to Robot Design: PicoCrickets*

- What is a robot? Sensors, actuators, and controllers.
- Introduction to the *PicoCricket*, a tiny robot controller.
- *PicoCricket* examples: *Happy Birthday, Movers and Shakers, My Pet Duck Dancing Crickets*, *Thermostat*, *Pickle-lo*.
- Introduction to *PicoBlocks*, a graphical programming language for the *PicoCricket*. actuator & sensor primitives; control flow (sequencing, conditionals, loops); procedural abstraction.
- Course administrivia.
- Level-triggered vs. edge-triggered events, variables, simple multitasking.
- *Challenge 1:* Build your own kinetic sculpture.

### Wednesday , January 7 (Class 2) *More Robot Programming; Handy Boards*

- Kinetic sculpture show-and-tell.
- The *PicoBlocks* text language.
- Introduction to the *Handy Board* and *Handy Logo*.
- Introduction to *SciBorg*, a pedagogical robot.
- *Challenge 2:* How does *SciBorg* follow a line?

### Thursday, January 8 (Class 3) More about SciBorg; LEGO Mechanics: Building Sturdy Structures

- Study *SciBorg* line-following code.
- *Challenge 3:* Simple *SciBorg* modifications (Homework).
- *Challenge 4:* Modify the *SciBorg* to do the following (Homework):

  1) **ping-pong** "bounce" back and forth between walls using front and rear touch sensors.

  2) **escape:** escape from barricaded surroundings.

  3) **sobriety-test** - improve *SciBorg* line-following behavior by minimizing constant weaving on relatively straight portions of track.

  4) **light follower** - get *SciBorg* to "home in" on a bright light source.
- *Challenge 5:* Sensor interaction (Homework).
- Overview of LEGO Technic components.
- Idioms for robust LEGO construction.
- *Challenge 6:* Build an "indestructible" LEGO box that can survive a 2 meter fall.

### Friday, January 9 (Class 4) *LEGO Mechanics: Gearing*

- *SciBorg* challenges discussion.
- Indestructible box discussion.
- *Challenge 7:* Pick one of the *PicoCricket* "motion modules" and build it by following the instructions. (Homework)
- Power transmission: motors, gear trains, speed vs. torque trade-off, friction, worm gears, bevel gears, differential gears, chains and treads.
- *Challenge 8:* Build a single-motor racing vehicle. The vehicle will participate in a 3 meter race carrying the *Handy Board* and a 1.0 kg mass.

### Monday, January 12 (No Class)

- Although there is no class today, we encourage you to continue to work on challenges and play with the equipment.

### Tuesday, January 13 (Class 5) *Iterative Design, Sensors*

- Testing and improving your racing vehicle designs, pre-race trials.
- Sensors: Analog vs. digital sensor, standard sensor configuration, simple electronics, detailed description of how reflectance sensor works, demonstration of various sensors. How to build your own sensors.
- *Challenge 9:* find 10 different kinds of sensors in your environment (dorm, classrooms, science center, campus, *etc*.) (Homework).
- *Challenge 10:* find an interesting animal sensor and write a couple of paragraphs about what it's used for and how it works (Homework).
- *Challenge 11:* auto-thresholding (Homework).
- Final project overview.

### Wednesday, January 14 (Class 6) Vehicle Races, Concurrency, Design Session

- Vehicle races.
- Concurrency: launching processes, when demons, stopping processes, process families.
- *Challenge 12:* decomposing behaviors using concurrency (homework).
- Robot project brainstorming.
- Show and tell: robots from previous years.
- Video festival: *Robo-Pong*, *The Way Things Go,* and more!

### Thursday, January 15 (Class 7)

- Pick teammates for final project.
- Begin work on preliminary robot project design: descriptions of behavior, sketches.
- Rapid prototyping demos: laser cutters and 3D printers.

### Friday, January 16 (Class 8) Preliminary Design Presentation, LogoChips

- Continue work on preliminary robot project design: descriptions of behavior, sketches.
- Present preliminary design to class for feedback.
- Begin implementation of robot projects.
- *LogoChips*: How to build your own programmable brick.
- Using WinSCP to save your work to your project account on Puma (the CS Department file server).

### Monday , January 19 (No Class; MLK Birthday)

Although there is no class today, this is a good time to brainstorm with your teammates on the design of your final project.

### Tuesday, January 20 (Class 9) *Robot Implementation*

- Groups continue to implement and document robots.
- Making web pages; how to incorporate picture and video into your robot project web pages.

### Wednesday, January 21 (Class 10) Web Page Design, Robot Implementation

- Web-page Tutorial
- Groups continue to implement and document robots.

### Thursday, January 22 (Class 11) *Robot Implementation*

- **Groups present current state of robots to get feedback.**
- Robot implementation and documentation continues.

### Friday, January 23 (Class 12) Robot Implementation) and In-Class Exhibit

- Robot implementation and documentation continues.
- **In-class demonstration of your robots for evaluation and filming.**

### Monday, January 26 (Class 13) *Robot Exhibition*

- Last-minute modifications to robots.

- Final filming of robots.
- Testing robots in the exhibit space (Sage Lounge, 2nd floor of Science Center).
- **Robot Exhibition**: 4:30--6pm in the Sage Lounge.
- **Cleanup Party:** 6 pm – 8 pm in SCI L024. Cleanup of room L024, accompanied with pizza**. All students are *required* to help with the clean up!**

### Tuesday/Wednesday, January 27 – 28 (No Class) *Wrap-up*

- **Individual design journals and group robot web pages due by 5pm in the box outside of Lyn's office (SCI E126).**