An integrated, quantitative introduction to the natural sciences

ISC/CHM/COS/MOL/PHY 231/2 **Fall 2008**

Lectures 10:00 to 10:50 AM, Monday through Friday in 101 Carl Icahn Laboratory (CIL).
For the first half of the semester, Tu/Th lectures are joint with COS 126, in 101 Friend Center.

Laboratories 1:30 to 4:20 PM, Monday or Tuesday in 012 Lewis Thomas Laboratories (LTL)

Precepts 1:30 to 4:20 PM, Wednesday or Thursday in 200 CIL.

Evening problem session 7:30 to ∼9:30 PM, Wednesday in the atrium of the CIL.

Scheduling issues you must solve: Students must enroll in *either* the Monday or Tuesday lab section, and *either* the Wednesday or Thursday precept. From our point of view these are independent decisions. Our only concern is that the different sections be roughly balanced; this is especially important for the lab, where the number of workstations is strictly limited.

Special notes for the first days of the semester:

- The first COS 126 lecture is on Thursday morning, 11 September.
- All students should attend a laboratory safety training session at 3 PM on Th 11 Sep, in the laboratory. If you have a scheduling conflict that makes it impossible for you to attend this session, please let us know immediately.
- There will be a COS precept in the first days of classes; this is important since there is an assignment due on M 15 Sep. Students enrolled in the Th precepts should go to precept at the regular time and place on Th 11 Sep. Students enrolled in the W precepts should go to Schultz 107 at 1:30 PM on F 12 Sep.

If you need help getting organized ... all administrative matters for the course are handled by Jennifer Brick (`jbrick@princeton.edu`). Jen is the person you see first when you enter the Carl Icahn Laboratory through the "uphill" (north) entrance, near the mailboxes. She also always knows how to find the faculty. A good person to know.

Faculty:

William Bialek (Physics & Lewis–Sigler Institute)
David Botstein (Molecular Biology & Lewis–Sigler Institute)
Curtis Callan (Physics)
Michael Desai (Lewis–Sigler Institute)
Matthias Kaschube (Lewis–Sigler Institute)
Leonid Kruglyak (Ecology and Evolutionary Biology & Lewis–Sigler Institute)
Ethan Perlstein (Lewis–Sigler Institute)
Robert Prud'homme (Chemical Engineering)
Joshua Rabinowitz (Chemistry & Lewis–Sigler Institute)
Eva–Maria Schötz (Lewis–Sigler Institute)
Olga Troyanskaya (Computer Science & Lewis–Sigler Institute)
Eric Wieschaus (Molecular Biology)
Ned Wingreen (Molecular Biology)

Note that some of the faculty will make their primary contribution in the Spring semester, and yet others contribute primarily to the sophomore course (235–6). The design of the integrated sequence is very much a group effort, however, and it seems appropriate to list everyone involved.

Assistants:

Yi Deng (lab assistant, Physics)
Julien Dubuis (course assistant, Physics)
Ana Pop (COS preceptor, Computer Science)
Audrey Sederberg (course consultant, Physics)
Jared Talbot (lab technician, Lewis–Sigler Institute)
Tao Yue (COS preceptor, Computer Science)

A few things to remember

1. This is **two** courses. For the first six weeks one course is COS 126, and you are responsible for everything they assign during this period, and the three hour precept time will be divided between COS and PHY/CHM topics. After the Fall break, we meet as one course, but the amount of work corresponds to two courses (and you get credit for two courses!).
2. You cannot learn the material without doing the problem sets. We have tried to write problems which are challenging, and hence probably require substantial effort, but without too much "busy work." On the other hand, some students feel more comfortable with some "warmup exercises" that aren't so hard. These can be found in standard textbooks, which also provide a more traditional point of view on the material of the course.
3. Learning involves talking with others about your thoughts and confusions. Science involves collaboration, and you should start now, which is why we schedule the evening problem sessions. What you turn in, however, must reflect your own understanding.
4. Laboratories are a serious part of the course. You will find many links among labs, lectures and problem sets. It is crucial that you read the lab notes *before* you come to the lab, so you can make the best use of the time available for doing experiments.
5. Everything you need to know or read will appear on the University's `blackboard` web site. We try to send emails each time something new is posted, but you should check regularly.
6. We expect you to read the lecture notes, including sections which don't correspond to actual lectures. Some of this material will be discussed in precepts and reinforced on problem sets.
7. Videotapes of the lectures will be available on `blackboard` two weeks after they are presented.

Grading

We hope that you are signing up for this course with a sense of adventure, and that we will succeed in conveying some of the excitement that we feel about science. Matching these ideals to the practical problem of grading is a work in progress, but we're trying. Full disclosure: Since we started offering the course in 2004, 143 students have taken 231/2, and their grades were A+ (9), A (37), A- (12), B+ (27), B (30), B- (17), C+ (10), C (1). Since this is two courses, you get two grades; we have been unable to find any sensible scheme other than to give the same grade twice (suggestions still welcome). We have no fixed policy about the numerical score required for a particular grade, but we do base your grade on the total number of points you accumulate during the semester. There are three components:

Problem sets, 30%. There will be ten problem sets during the semester, plus the assignments for the first six weeks of COS 126. The longer problem sets after the Fall break will be given proportionately more weight. We have tried to distribute the work in a reasonable way throughout the semester, but this is hard to get right, and we appreciate your feedback.

Laboratory work, 30%. Laboratory grades are determined by four lab reports, one for each lab module. Lab reports should be no more than five pages long and are due at the beginning of your lab session one week after the module ends. Late lab reports will have points deducted. Specific instructions for the material to be covered in each report will be discussed in class. Although the labs vary in length, each of the four lab reports is given equal weight in computing your grade.

Exams, 40%. There will be two midterm exams (one from COS 126 and one from the rest of the course), each two hours long, and a three hour final exam. Each hour segment will count equally, and we will drop the lowest of these seven grades.

We try to be accommodating if illness or personal issues take you away from class. Laboratory sessions are especially difficult to make up for, however. If complications arise, please arrange for your residential college dean or director of studies to contact us.

A few philosophical remarks

This course is a collaboration among many faculty. We also like to think of it as a collaboration between the students and the faculty. What we are trying to do is new and unconventional, and we are all in it together. To make this work, we encourage a high level of interaction. Please don't be shy to ask questions during lectures, and to ask why you are doing things in the lab. As noted above, we expect you to work together on problem sets, and we hope that doing the problems promotes your own independent thinking about the ideas in the course. We need to hear from you about how we are doing in conveying both the substance and spirit of the material.

Getting help if you need it

We are putting a lot of ourselves into the course, and we know that we are asking a lot from our students. We hope that you find this exciting. At the same time, we understand that there may be moments when it all seems a bit too much (rest assured, the faculty has those moments too!). We want to emphasize that there are many resources available to help you through any difficulties which might come up. Faculty, assistants, and your fellow students all are sources of information about the course material. Multiple tutoring programs are organized by your residential colleges, by the McGraw Center, and by a group of seniors who took the course when they were freshmen. More details about all of this will be announced as the course proceeds. All of us are committed to helping you get the most out of your experience in the course.

Remember that, in addition to the lecture schedule given here, you attend one laboratory session and one precept each week!

Introduction

Th 11 Sep (COS 126)
F 12 Sep A physicist's point of view (WB)
M 15 Sep A biologist's point of view (DB) ..... COS assignment 0 due
Tu 16 Sep (COS 126)
W 17 Sep A chemist's point of view (JR) ..... evening problem session
Th 18 Sep (COS 126)

The introductory laboratory module *Theory and measurement: Moving through fluids* will run for two weeks, 15/16 & 22/23 September. The report on this module is due 29/30 September; reports should be turned in during your lab section unless otherwise noted.

Dynamical models

Newton's laws, chemical kinetics, ...

F 19 Sep Starting with $F = ma$ ... (WB) ..... Problem set 1 due
precept topic MATLAB intro & math review (MG & MK)[1]
M 22 Sep From boxes and arrows to differential equations (WB) ..... COS assignment 1 due
Tu 23 Sep (COS 126)
W 24 Sep Radioactive decay and the age of the solar system (WB) ..... evening problem session
Th 25 Sep (COS 126)
F 26 Sep Second order kinetics and the complexity of DNA (DB) ..... Problem set 2 due
precept topic Solving differential equations with computers (MK)

Resonance and response

M 29 Sep The simple harmonic oscillator (WB) ..... COS assignment 2 due
Tu 30 Sep (COS 126)
W 1 Oct Complex exponentials (WB) ..... evening problem session
Th 2 Oct (COS 126)
F 3 Oct Damping, phases and all that (WB) ..... Problem set 3 due
precept topic Simple circuits and population dynamics (MD)
M 6 Oct Linearization and stability (WB) ..... COS assignment 3 due
Tu 7 Oct (COS 126)
W 8 Oct Linearization and stability, continued (WB) ..... evening problem session
Th 9 Oct (COS 126)
F 10 Oct Stability in a real genetic circuit (NW) ..... Problem set 4 due
precept topic More on complex exponentials (MK)
M 13 Oct The driven oscillator (WB) ..... COS assignment 4 due
Tu 14 Oct (COS 126)
W 15 Oct Resonance in the cell membrane (WB) ..... evening problem session

[1] This precept (and, as needed, some of the next) will be led in part by Michael Gelbart '10.

Th 16 Oct (COS 126)
F 17 Oct (allowance for slip) ..... Problem set 5 due
precept topic More on stability (MK)
We are not the center of the universe[2]
M 20 Oct Conservation of energy (WB)[3] ..... COS midterm (evening)
Tu 21 Oct (COS 126)
W 22 Oct Conservation of $\vec{P}$ and $\vec{L}$ .....evening review session
Th 23 Oct (COS 126) .....ISC midterm (evening)
F 24 Oct Symmetries and conservation laws (WB)
precept topic Using the conservation laws (MK)

The laboratory module on dynamics, *Exponential behavior: Measuring bacterial growth*, will run for six weeks, 29/30 September through 10/11 November, spanning the fall break. The report on this module is due 17/18 November.

Assignment over Fall break. By the time you leave for Fall break, problem sets 1–4 should have been graded and returned to you, with solutions. During the break, we encourage you to go over your previous work and to understand/correct your mistakes. As an incentive, if you turn in reworked problem sets, you can receive half the difference between your original score and full credit. Thus if you got 8/10 on a problem and you submit a clearly revised and correct version, your score will move to 9/10. It should be clear that copying the solution set is not appropriate; we want you to get in the habit of going back over your work to increase your understanding. Also, to make the task manageable for the AIs, we will not give partial credit: If you clearly fixed things up, you move from 8/10 to 9/10, but if you sort of improved things but didn't really get it, you stay at 8/10 (not 8.5!). Since you have access to the solution sets, this doesn't seem too harsh.

Probabilistic models

Genes, combinations and probability
M 3 Nov Introduction to genetics (DB) ..... revised problem sets due
Tu 4 Nov More on recombination (LK)
W 5 Nov Distributions, measurement and likelihood (LK) .....evening problem session
Th 6 Nov Conditional probability and inference (LK)
F 7 Nov Probabilistic inheritance (DB)
precept Practice with probabilities (MD)
The Boltzmann distribution
M 10 Nov From boys and girls to Boltzmann (WB) .....Problem set 6 due
Tu 11 Nov The gas laws and the meaning of T (WB)
W 12 Nov The partition function (WB) .....evening problem session
Th 13 Nov Entropy (WB)
F 14 Nov Rearranging the sums (WB)
precept Using the Boltzmann distribution (MK)
Chemical thermodynamics[4]
M 17 Nov Gibbs free energy (RP) ..... Problem set 7 due[5]

[2] We will return to these issues at the end of the course.
[3] Since this is midterm week, no new problems will be assigned.
[4] The list of lecture topics here is more tentative; please look to `blackboard` for revisions.
[5] No new problem set this week because of the Thanksgiving recess.

Tu 18 Nov	Thermochemical calculations (RP)
W 19 Nov	Chemical potential (RP) . . . . . evening problem session
Th 20 Nov	Chemical equilibrium (RP)
F 21 Nov	Physical equilibrium (RP)
precept	More chemical concepts (tba)
M 24 Nov	Electrochemical potentials (RP)
Tu 25 Nov	Oxidation–reduction reactions (RP)
W 26 Nov	Chemical kinetics (RP)
	(Thanskgiving recess, no precept or problem session)
M 1 Dec	Reaction rate theory (RP)
Tu 2 Dec	Michaelis–Menten kinetics (RP)
	From Boltzmann to Brownian motion
W 3 Dec	From equipartition to the Langevin equation (WB) . . . . . evening problem session
Th 4 Dec	Brownian motion and random walks (WB)
F 5 Dec	Einstein relations and the evidence for molecules (WB) . . . . . Problem set 8 due

Picking up some loose ends ...

	We are not the center of the universe, continued
M 8 Dec	Universality of gravitation (WB)
Tu 9 Dec	Kepler's laws I (WB)
W 10 Dec	Kepler's laws II (WB) . . . . . evening problem session
Th 11 Dec	Biological counterpoint (DB)
	And, finally,
F 12 Dec	A last word about entropy (WB) . . . . . Problem set 9 due
precept	Simulating random events (MK)

There are two laboratory modules dealing with the issues of probabilistic models, each lasting two weeks: *Mutation rates in yeast* runs 17/18 and 24/25 November, with the report due 1/2 December. *Brown, Boltzmann and Avagadro* runs 1/2 and 8/9 December, with the report due M 5 Jan, the start of reading week (in the course mailbox).

And in 2009 ...

M & Tu 5/6 Jan	precepts meet to discuss material from last week of lectures (at usual lab times)
W 7 Jan	. . . . . evening problem session
F 9 Jan	. . . . . Problem set 10 due
M 12 Jan	Review session (time TBA)
Tu 13 Jan	Review session (time TBA)