Physics 42 Syllabus

This is the second of a two semester sequence in introductory physics, covering electrostatics, magnetostatics, the electromagnetic wave equation, and light, *with calculus*. Its intended targets are physics majors or minors (where it is the recommended but not mandatory sequence), math majors, and selected students of engineering and the sciences. It is mathematically more rigorous and conceptually more demanding than the physics 53/54 sequence that otherwise has almost the same syllabus, or the physics 61/62 (engineering) sequence that has a more limited syllabus, and is hence intended for students of science or engineering who seek a more challenging and complete introduction to the subject.

As of 2010, the course will only require the use of the online textbook located here:

http://www.phy.duke.edu/~rgb/Class/intro_physics_2.php

although it is in rough correspondance with the chapter progression in many textbooks in introductory physics such as Tipler, or later Tipler and Mosca's *Physics for Scientists and Engineers* in whatever edition you can find. Any or all such textbooks can be used to supplement the presentation or examples in the online textbook, but they are not required for the course.

This textbook is deliberately designed to be maximally useful to the student in three important ways. First, the chapters are deliberately designed to be covered in one "standard semester-week" – three hours of lecture plus three to five hours of homework followed by two hours of recitation. There are slightly fewer chapters than weeks, allowing for e.g. spring or fall break and a certain amount of catchup. Second, the chapters are organized with the chapter summary *first*, lecture note style, so that students can *quickly* skim the chapter content before lecture, before homework, as the first part of review, and can use the overview thus gained to provide a skeleton upon which to hang the increased detail and examples of the text body. This body is presented in a purely derivational algebraic style, without irrelevant numbers, so that the *structure* of physics is laid bare without distractions, and with examples typically collected to follow the exposition instead of being embedded in it. Third, following each chapter there is a *short* list of relatively *difficult* problems (again, generally without any use of specific numbers). The textbook is designed to support both ordinary science or engineering students and physics majors; in both cases students should do *all the problems marked for their level* which in the case of majors, is all of the problems! Non-majors skip certain problems that explore relatively advanced concepts or that require a slightly higher degree of comfort with mathematics.

There are other advantages in the layout: It contains a self-contained description of all of the mathematics required in the course, permitting the mathematically weak student to review almost anything without having to find a math textbook that they may no longer own. It is available for *free* in an online form, and very inexpensively as a PDF download or paper copy (certainly compared to the average price of current physics textbooks at the same level). Although it is relatively terse, it is also exhaustive and treats the material quite thoroughly at the level of physics *with* calculus including a moderately rigorous in-place treatment of second order linear differential equations as needed. And finally, it is supplemented by an extensive list of review problems at the level of the course – basically every problem I've ever given on a quiz or hour exam, every problem I've found that *other people* have given on hour or final exams appropriate for the level of the material. Any student that completes the homework and is successful with the review problems is very, very likely to excel in the course gradewise.

Note to Students

Physics 42 and physics 54 (at Duke) have the same syllabus; the only real difference between the two courses is the level of mathematics required in the problems and examples – in physics 54 problems likely to require *strong* multivariate calculus concepts are omitted from the in-class examples, the homework, and test questions. However, the standard Duke introductory physics curriculum *includes calculus* (both integral and differential) and so simple (separable) 2 and 3 dimensional integrals may be demonstrated, and *where demonstrated*, required of the student in physics 54. In physics 42, selected "advanced" homework problems are assigned, intended to introduce the students non-rigourously to ideas such as the divergence theorem to help prepare them for later courses, but these problems will generally not be tested.

Students at *all* levels are expected to be able to differentiate and integrate simple functions such as u^n, $\sin(u)$, $\cos(u)$, e^u, as well as know how to do u-substitution, use the chain rule, know how to differentiate a product, know how to integrate by parts, understand concepts in trigonometry, plane geometry, vectors (including both dot and cross products), and algebra (including how to solve single equation for an unknown variable, simple sets of simultaneous equations, the quadratic formula, and complex numbers). Knowledge of at least two dimensional Cartesian and Plane Polar coordinate systems is assumed, knowledge of three dimensional Cartesian, Cylindrical and Spherical Coordinates is preferred (especially for physics 42 students) although it will be taught as required in a self-contained way where required.

List of Topics

The following topics are covered at the rate of approximately one per week during the regular semester, three per week in summer school:

- **Discrete Charge and the Electric Field:** Charge, Coulomb's law, electrostatic field, superposition principle, electric dipoles.

- **Continuous Charge and Gauss's Law:** Continuous charge distributions, field of loop, line, disk, sphere of charge, Gauss's law for electrostatic field, Gauss's law used to find fields of point/sphere, line/cylinder, plane/slab distributions of charge, properties of conductors, Gauss's law and conductors.

- **Electrostatic Potential Energy:** Potential energy of two interacting charges, potential, superposition principle, computing potential from fields, computing potential using superposition, conductors in electrostatic equilibrium, charge sharing, dielectric breakdown.

- **Capacitance and Resistance:** Capacitance, plane capacitors, cylindrical capacitors, spherical capacitors, capacitance in series and parallel, dielectrics, dielectrics and capacitance. Resistance, resistivity/conductivity, Ohm's law, resistors in series and in parallel. RC circuits (charging and discharging).

- **Magnetic Force:** Force on point charge in given $\vec{B}$ field, force on current carrying segment of wire, motion of point charge in uniform field, cyclotron frequency, velocity selector, cyclotron, Thomson's apparatus for measuring e/m, mass spectrometer, Hall effect, magnetic dipole (moment), force and torque on magnetic dipole, potential energy of magnetic dipole.

- **Magnetic Field:** No isolated monopoles, Gauss's law for magnetism, field of a moving point charge, Biot-Savart law, field of long straight wire carrying current, a ring carrying current, a rotating disk of charge, Ampere's law, using Ampere's law to find the field of wire/cylinder, solenoid, toroidal solenoid, infinite sheet of current.

- **Faradaw's Law and Induction:** Motional potential differences, motional currents in loops, Faraday's law, Lenz's law, Lenz's law and energy conservation, magnetic flux and inductance, mutual inductance, self inductance, self inductance of solenoid, toroidal solenoid, solenoid as generic inductor L, voltage across an inductor, mutual inductance and transformers,

- **Alternating Current Circuits:** AC generator, household voltage, current, wiring true facts and dangers, transformers and power transmission (Tesla vs Edison feud), LC circuit, LRC circuit, harmonically driven series LRC circuit (reprise of simple harmonic oscillator, damped harmonic oscillator, damped driven harmonic oscillator, resonance and power curves, $V_{\rm rms}$ and $I_{\rm rms}$, Q, high pass and low pass filters, impedance, parallel LRC circuit.

- **Maxwell's Equations and Light:** Non-invariance of Ampere's law, charge conservation and invariant current, Maxwell Displacement Current, Maxwell's Equations (as a complete set), derivation of (homogeneous) wave equation for $\vec{E}$ and $\vec{B}$ fields in free space, speed of light, solutions to wave equation, especially harmonic solutions, energy density in electromagnetic field, intensity of light and the Poynting vector, power as flux of Poynting vector, momentum in electromagnetic waves, radiation pressure, dipole antenna, accelerating charges and failure of classical physics.

- **Properties of Light:** Speed of light in a medium, index of refraction, dispersion, law of reflection, Fermat principle, law of refraction (derivation of Snell's law from wave geometry), polarization of light (definition), polarization by absorption (Malus's law), scattering, reflection, how/why polarized sunglasses work, scattering and why sky is blue (Rayleigh's law), non-relativistic doppler shift, Cerenkov radiation in a medium, Huygens principle.

- **Mirrors and Lenses:** Ray approximation and how rays are emitted in all directions from all points on object, plane mirror, definition of object, image, object distance, image distance, magnification, real image, virtual image, erect image, inverted image, ray diagram, spherical mirrors in paraxial approximation (including derivation of equation linking s, s', f), ray diagrams with parallel, focal, central rays, spherical lenses, thin lenses, lensmakers formula, thin lens equation, ray diagrams for lenses.

- **The Eye and Optical Instruments:** The eye, especially lens, pupil, and retina, normal vision, nearsighted vision, farsighted vision (and corrections), simple magnifier, telescope, "Galilean" (non-inverting) telescope, compound microscope, "Galilean" (non-inverting microscope, aberrations.

- **Physical (Wave) Optics:** Huygens principle revisited, thin film interference, two slit interference (and phasors revisited), three slit, four slit... N slit interference (via phasors), diffraction through single slit, combined two slit interference and diffraction, diffraction grating, Rayleigh criterion for resolution, radio telescope arrays.

Tentative Schedule

The following is a *tentative* schedule for the *current* semester (Spring 2010). It probably will not survive intact, as I tend to slow down when people have trouble and speed up when it is smooth sailing, which varies year to year. But it is *a* schedule that will carry us through the material in a timely way, and complete all the required work in the allotted time.

Note that this has all the assignments for the semester, at least as of now. The assignment rule is simple – as we complete each chapter, do all of the homework at the end (all unstarred problems for 54, all problems for 42). Use the method of three passes to do the homework if at all possible. The homework will be reviewed, in groups, with tutorial assistance in recitation, followed by a quiz of similar difficulty to upper-third problems (but usually not starred problems).

You then have *two days* to write up your homework and hand it into the box, where you are welcome to contact me or the TA for help finishing any problem(s) that were still not clear at the end of recitation.

Students are *strongly urged* to come to recitation with their homework at least *70% completed* in several work passes prior to recitation, so that they have a good chance of getting through the last few (usually quite difficult) problems *in* recitation with the help of your group members and the course mentors. If this does not occur, your quiz grade will inevitably reflect it, and your final grade will thereby suffer. Also, you won't have as much *fun* in recitation if you aren't participating as a *contributor* to the discussions on each problem. So please invest the time needed to make recitation a pleasant and productive experience for yourself and your fellow group members!

Day	Chapter	Assignment
January 13-15	Week 1	Week 1 HW (Due 01/22)
January 18-22	Week 22	Week 2 HW (01/29)
January 25-29	Week 3	Week 3 HW (02/5)
February 1-5	Week 4	Week 4 HW (02/12)
February 8-12	Week 5	Week 5 HW (02/19)
February 15-19	Week 6	Week 6 HW (02/26)
Feb 22	Hour Exam 1 (Weeks 1-4)	In Lab
Feb 22-26	Week 7	Week 7 HW (03/05)
March 1-5	Week 8	Week 8 HW (03/12)
March 8-12	Spring Break	Spring Break
March 15-19	Week 9	Week 9 HW (03/26)
March 22-26	Week 10	Week 10 HW (04/2)
March 29	Hour Exam 2 (Weeks 5-8)	In Lab
March 29-April 2	Week 11	Week 11 HW (04/9)
April 5-9	Week 12	Week 12 HW (04/16)
April 12-16	Week 13	Week 13 HW (04/23)
April 19-23	Catch up	Catch up
April 26	Hour Exam 3	In Lab
April 28	Last Day of Class	Last Day of Class
May 5	Final Exam, 7:00-10:00 p.m.	Room 150