Physics 2030—Fundamentals of Physics III
Fall 2012
High Point University

Syllabus

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Web: http://physics.highpoint.edu/∼atitus/; Facebook: https://www.facebook.com/physicslogos; Twitter: @physicslogos . You can also add me to your circles on Google+ (hpuphysics@gmail.com).

My personal mission is to encourage you to be a life-long, interdisciplinary learner. If you are teachable, motivated, and diligent, you will be successful.

My educational philosophy is that you learn best when you are actively engaged with the subject through activities such as reading (and answering questions about what you read), discussing, experimenting, and solving problems. Lectures are useful for motivation and synthesis, but for most students merely listening to lectures and copying lecture notes is an ineffective method to learn. It's when you study individually, think deeply about the subject, ask questions, develop ideas and test them, and subsequently dialogue with classmates and the professor that you learn the most. My role as the professor is to create an environment that promotes active-learning, to assess your learning, and to provide guidance and mentorship along the way.

I expect you to learn the tools of scientific exploration that we will use in this class, including laboratory methods and equipment and computational modeling. In this course you will do an independent project. I hope that you will better understand the nature and process of science as a result of taking this course.

I reserve the privilege to change this syllabus based on feedback from you and what I determine is best for the course. If the syllabus is changed, you will receive an electronic copy of the updated version.

Course Description: An introduction to space-time physics and quantum physics with applications in astronomy, atomic physics, solid-state physics, nuclear physics, and particle physics. Four credits. Prerequisite: PHY 2020. Offered Fall Semester.

Lecture: TTh 9:45 AM – 11:25 AM, Rm 129. **Lab:** TTh 8:00 – 9:30 AM, Rm 129. You are expected to do at least 5 h of work outside of class each week, including reading, solving problems, and working on your class project.

Office Hours: TTH 3:00 – 5:00 PM. I will also be available online Sunday − Thursday from 10:00 PM – 11:00 PM.

Textbook(s): *Six Ideas that Shaped Physics* by Thomas Moore. We will use the 2nd edition of Unit R (Relativity) and Unit Q (Quantum). It is published by McGraw Hill.

Course Web Site: http://physics.highpoint.edu/∼atitus/courses/phy2030/

Grading Scale (min% weighted average): A+ (97), A (93), A− (90), B+ (87), B (83), B− (80), C+ (77), C (73), C− (70), D+ (67), D 63, D− (60), F (<60). I reserve the right to decrease the minimum scores if it is appropriate.

Assessment: proficiency with standards (90%); class project (10%).

We will use a different approach to assessment called Standards-Based Grading (SBG). Each chapter has a list of standards. You will solve problems, write computer programs and do experiments to show your understanding (i.e. proficiency) on each standard. We will have periodic quizzes, exams, and collaborative problem solving sessions where you can demonstrate proficiency on each standard. You will also be given example problems that you can use to show your proficiency. At any time, you can re-assess to demonstrate your proficiency. Your grade is not "final" until the end of the semester and you can use the entire semester to demonstrate your understanding, reassessing as many times as is needed. However, when being reassessed, it's possible for your proficiency to decrease as well.

I am using SBG to address the following problems with traditional assessment:

- Sometimes one focuses on points instead of learning.

- When one “bombs” an exam, there is no incentive to study the material that one did not understand. In addition, one loses the points on that exam even if the material is understood by the end of the semester.
- When you get a grade on an exam, like 70%, it might mean that you understood 70% of the content and do not understand 30%. The overall score does not tell you which concepts/skills you are proficient at and which ones you still need to study or practice. By tying each question on an exam to a standard and grading each question (not the exam), you know exactly which standards you still need to study.
- Cramming for an exam is rewarded, not the habits that lead to life-long learning like persistence and independence.

You will sometimes turn in written work and will sometimes turn in a screencast (using Jing) where you discuss your solution. You can also demonstrate proficiency by solving a problem in front of the professor (i.e. an oral exam). You will be graded on either a 2-pt scale or a 4-pt scale for each standard. The rubric for the scale is shown below and is borrowed from Andy Rundquist who cites Frank Noschese.

Your course grade on the standards will not be announced until after the midterm. Your focus should be on demonstrating understanding of the standards, instead of the course grade.

4 level scale

1. Not assessed: 0
2. Doesn’t meet expectations: 1
   (a) I need lots of help from my instructor (one-on-one).
   (b) I have low confidence on how to do the skills and need more instruction.
   (c) I need my textbook/notes at all times.
   (d) I do not understand the concept/skills.
   (e) I cannot correctly identify concepts and/or define vocabulary.
   (f) I cannot make connections among ideas or extend the information.
   (g) My responses lack detail necessary to demonstrate basic understanding.
   (h) Cannot articulate most of the main ideas involved in the standard
3. Approaches expectations: 2
   (a) I have a general understanding of the content/skills, but I’m also confused about some important parts.
   (b) I need some help from my instructor (one-on-one or small group) to do the skills correctly
   (c) I do not feel confident enough to do the skills on my own
   (d) I need my textbook/notes most of the time.
   (e) I can correctly identify concepts and/or define vocabulary; however I cannot make connections among ideas and/or independently extend my own learning.
   (f) My responses demonstrate basic understanding of some main ideas, but significant information is missing.
4. Meets expectations: 3
   (a) I understand the important things about the content/skills.
   (b) I have confidence on how to do the skills on my own most of the time, but I need to continue practicing some parts that still give me problems.
   (c) I need my handouts and notes once in a while.

   (d) I am proficient at describing terms and independently connecting them with concepts.
   (e) I understand not just the "what," but can correctly explain the "how" and "why" of scientific processes.
   (f) My responses demonstrate in-depth understanding of main ideas.

5. Exceeds expectations: 4
   (a) I understand the content/skills completely and can explain them in detail.
   (b) I can explain/teach the skills to another student.
   (c) I have high confidence on how to do the skills.
   (d) I can have a conversation about the skills.
   (e) I can independently demonstrate extensions of my knowledge.
   (f) I can create analogies and/or find connections between different areas within the sciences or between science and other areas of study.
   (g) My responses demonstrate in-depth understanding of main ideas and of related details.

2 level scale

1. Does not meet: 0
2. Meets: 1

Organization of class time: Most days will begin with a reading quiz that covers the chapter content and exercises that you should have completed before coming to class. Reading quizzes and Two-Minute Problems are used for self-evaluation to assess how much you retained from reading the chapter. Daily preparation and participation is absolutely required for your success in the class, as well as the success of your classmates. Each class will be arranged according to the following schedule:

1. Reading quiz and Two-Minute Problems
2. Chapter review and discussion
3. Activities and simulations
4. Cooperative group problems
5. Summary of big ideas

Quizzes: There will be three 100-minute long quizzes. Quizzes will typically consist of two or three of the following sections: (1) conceptual and numerical multiple choice questions; (2) problem solving; (3) computational modeling. All quizzes and the final exam are comprehensive and can include any standards that are "live" up to that point in the semester.

Final Exam: Tuesday, Dec. 10, noon – 3:00 PM.

Project: You will do a class project that is experimental, computational, or theoretical in nature. The project must be approved by Dr. Titus. It must be related to topics in the course.

There are five categories that the project's grade is based on.

1. level of difficulty
2. level of creativity
3. level of independence

4. completeness (i.e. ”Does the simulation run and give correct results?” or ”Did you report uncertainties in your measurements?” or ”Did you include relevant background material and references”)
5. quality of presentation and/or paper

You should:

1. write a paper of appropriate length (≈ 5000 words is a rough estimate) that describes the details of your project. LaTeX is required. Templates are at: <`http://physics.highpoint.edu/Physics/LaTeX.html`> .
2. present your project to the class.

Expectations: Expect to work hard, to be challenged, to learn, and to work together.

Accommodations: Students who require classroom accommodations due to a diagnosed disability must submit the appropriate documentation to Disability Support in the Office of Academic Development, 4th Floor Smith Library. Students' needs for accommodations must be made at the beginning of a course. Accommodations are not retroactive.

Attendance: If you have more than two unexcused absences, you can be withdrawn from the class. I reserve the right to choose whether to withdraw you or not for lack of attendance.

Schedule: A tentative schedule of lectures is given in Table 1.

Table 1: Tentative Schedule of Class Meetings

Day No.	**Date**	**Chapter**
1	8/20	R1
2	8/22	R2
3	8/27	R3
4	8/29	R4
5	9/3	R5
6	9/5	R6
7	9/10	R7
8	9/12	R8
9	9/17	Quiz 1
10	9/19	R9
11	9/24	R10
12	9/26	Q1
13	10/1	Q2
14	10/3	Q3
15	10/8	Q4
16	10/10	Quiz 2
17	10/22	Q5
18	10/24	Q6
19	10/29	Q7
20	10/31	Q8
21	11/5	Q9
22	11/7	Q10
23	11/12	Quiz 3
24	11/14	Q11
25	11/19	Q12; interim project report is due
26	11/21	Q13
27	11/26	Q14
28	11/28	Thanksgiving
29	12/3	project presentations
	12/10	final exam

Table 2: Standards (up through Q10)

Chapter	Name	Standard
	LApparatus	I can use a lab apparatus with appropriate technique to make measurements accurately and precisely.
	LReport	I can write a lab report in LaTeX in a style consistent with a journal article that describes the experiment, measurements, and conclusions.
R1	Rel	I can state the Principle of Relativity and can apply it to non-relativistic motion
R2	SR	I can provide evidence for Special Relativity and can apply SR to relativistic motion
R3, R4, R5	Time	I can measure or calculate position, coordinate time, proper time, and spacetime interval, and I know what quantities are invariant.
R6	LT	I can calculate (and compare) spacetime coordinates of an event for observers in different inertial frames.
R7	LC	I can calculate (and compare) length measurements for observers in different inertial frames.
R8	V	I can calculate (and compare) velocity measurements for observers in different inertial frames.
R8	Causality	I can determine whether two events are causally related.
R8, R9, R10	4Mom	I can calculate mass, momentum, energy, and 4-momentum for a particle, and I know which quantities are invariant and which quantities are conserved.
R10	Cons	I can apply conservation of 4-momentum to a system.
Q1	WS	I can describe the modes of a standing wave (whether transverse or longitudinal) whether it is fixed at both ends or free and fixed at each end.
Q2	WI	I can use path difference to predict the interference of two sources of waves at a location.
Q3, Q4	WP	I can provide evidence for wave-particle duality and can apply a particle model or a wave model to a quanton, depending on the experiment.
Q5	MQ	I can use the mathematics needed to describe the state of a quanton, including complex algebra, the inner product of two complex vectors, probability, and normalization.
Q5, Q6	Qrules	I can recite and apply the ”rules of the game” of quantum mechanics.
Q7, Q8	Qenergy	I can derive energy eigenvalues for various systems and can relate energy eigenvalues to a spectrum of photons emitted or absorbed.
Q9	QH	I can describe the set of quantum numbers for a hydrogen atom and can connect these quantum numbers to various representations of the atom, including spectroscopic notation, an energy diagram, and a plot of the real part of the square of the associated energy eigenfunctions.
Q9	Qatom	I can describe how multi-electron atoms are similar to and different from the hydrogen atom and the implications on energy eigenvalues and allowed transitions.
Q10	Qpsi	I can write a VPython program to calculate Psi numerically for a given value of E and graph Psi(x). I can use this program to find the energy eigenvalues of a system.

Table 3: Evidence (up through Q10)

Chapter	Name	Evidence
R1	Rel	I can state the Principle of Relativity and can apply it to non-relativistic motion
	R1	I can design a test for whether a reference frame is inertial or not and can identify inertial reference frames.
	R1	I can state the Principle of Relativity.
	R1	I can derive the Galilean transformation equations for position and velocity and can use them to make predictions of what an observer in a particular inertial reference frame would measure.
	R1	I can describe how clocks are synchronized in Newtonian Relativity and what measurements observers in inertial reference frames will agree on.
R2	SR	I can provide evidence for Special Relativity and can apply SR to relativistic motion
	R2	I can explain the "problem with electromagnetic waves" and the experiment(s) that showed the non-existence of the ether.
	R2	I can describe how clocks are synchronized in Special Relativity.
	R2	I can convert between SI units and SR units.
	R2	I can sketch and interpret worldlines on a spacetime diagram.
R3, R4, R5	Time	I can measure or calculate position, coordinate time, proper time, and spacetime interval, and I know what quantities are invariant.
	R3	I can define coordinate time, proper time, and spacetime interval and can describe how each quantity is measured. I can use a geometric analogy with spacial coordinates to describe each quantity, thus comparing plane geometry and spacetime geometry.
	R3	I can explain why events that are simultaneous in one inertial frame are not simultaneous in another frame.
	R4	Use the metric equation to calculate spacetime interval.
	R4	I can explain the Twin Paradox using a spacetime diagram and a calculation of spacetime interval for each twin.
	R4	I can calculate the number of muons remaining after x number of half-lives, and I can explain, using the metric equation, why fewer muons decay that is predicted by classical physics.
	R5	I can calculate the proper time along a curved worldline traversed by an inertial clock moving at constant speed.
	R5	I can derive and use the bionomial approximation.
	R5	I can describe and give examples to explain the relationship between coordinate time, spacetime interval, and proper time, as shown in Figures R5.1 and R5.2.
R6	LT	I can calculate (and compare) spacetime coordinates of an event for observers in different inertial frames.
	R6	I can draw a two-observer diagram, with correctly sloped t' and x' axes and correctly calibrated scales, and can plot and read the spacetime coordinates of events.
	R6	I can use a two-observer diagram to transform coordinates of an event from one frame to another frame and can use the two-observer diagram to solve problems and make predictions.
	R6	I can use the Lorentz Transformation Equations (and Inverse Lorentz Transformation Equations)

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Chapter	Name	Evidence
R7	LC	I can calculate (and compare) length measurements for observers in different inertial frames.
	R7	I can state an operational definition for the length of an object.
	R7	I can use a two-observer diagram to determine the length of an object as measured in an Other frame.
	R7	I can calculate the Lorentz contraction of an object
R8	V	I can calculate (and compare) velocity measurements for observers in different inertial frames.
	R8	I can use the Einstein velocity transformation equations to calculate the velocity of an object measured by an observer in an Other frame (or alternatively, the Home frame).
R8	Causality	I can determine whether two events are causally related.
	R8	I can determine whether the interval between events is timelike, lightlike, or spacelike and can describe how each interval is measured.
	R8	I can determine whether two events are causally related.
	R8	I understand The Cosmic Speed Limit and that it results from Causality being consistent with the Principle of Relativity
R8, R9, R10	4Mom	I can calculate mass, momentum, energy, and 4-momentum for a particle, and I know which quantities are invariant and which quantities are conserved.
	R8	I can show that the classical definition of momentum as p=mv is inconsistent with the Principle of Relativity and Conservation of Momentum
	R9	I know the definition of mass as the magnitude of the 4-momentum of an object, and I know that it is the same for observers in different inertial reference frames (i.e. it is invariant).
	R9	I can write the total energy of a particle in terms of its rest energy and kinetic energy, in both SR units and SI units.
	R9	I can use the equations in Figure R9.5, and I know where each equation comes from.
	R9	I can use Einstein transformation equations to transform the 4-momentum of an object in one inertial frame to the 4-momentum of the object measured in another inertial frame.
	R10	I can sketch and interpret an energy-momentum diagram.
R10	Cons	I can apply conservation of 4-momentum to a system.
	R10	I can apply conservation of 4-momentum to a system, including a system with photons. I know that photons have no mass but do have energy and momentum (E=p).
	R10	I know that the mass of a system is generally different than the sum of the masses of its parts; I can explain why this is the case using conservation of energy and E=m+K; and I can give an example showing this to be true.
	R10	I can use a momentum-energy diagram to show conservation of 4-momentum for a system.
Q1	WS	I can describe the modes of a standing wave (whether transverse or longitudinal) whether it is fixed at both ends or free and fixed at each end.
	Q1	I can derive equations Q1.12a and Q1.12b.

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Chapter	Name	Evidence
	Q1	I can state the superposition principle and can add waves graphically and algebraically.
	Q1	I can describe the shape of a reflected wave at an interface between two media or at a boundary with a fixed or free end.
	Q1	I can derive equation Q1.9 and can use it to describe the motion of various pieces of the medium for a standing wave.
	Q1	I can identify the boundary conditions and can calculate the frequency of the normal modes of a standing wave.
Q2	WI	I can use path difference to predict the interference of two sources of waves at a location.
	Q2	I can calculate the path difference at a given location from two sources and can predict whether it will result in total constructive interference or total destructive interference or something in between.
	Q2	I can calculate the locations of bright fringes in a double-slit experiment, and I can describe how fringe spacing depends on wavelength and slit spacing.
	Q2	I can calculate the locations of dark fringes in a single-slit experiment.
	Q2	I can use the Rayleigh Criterion to describe whether two point sources can be resolved.
	Q2	I can use a single-slit interference apparatus to determine the wavelength of a light source, including uncertainty.
Q3, Q4	WP	I can provide evidence for wave-particle duality and can apply a particle model or a wave model to a quanton, depending on the experiment.
	Q3	I can describe the photoelectric effect experiment and can use the photon model for light to explain the results, explain and interpret a graph of maximum kinetic energy vs. frequency, and make predictions.
	Q3	I can use a photoelectric effect apparatus to conduct an experiment to measure Planck's constant and the work function of the metal.
	Q3	I can calculate the energy of a photon and relate energy to frequency (or wavelength) of light.
	Q3	I can relate the number of photons per second incident on a surface and intensity of light for a given power of a light source. I also understand the difference between a point source of light and a beam of light in terms of how its intensity varies with distance.
	Q4	I can compute the deBroglie wavelength of a particle.
	Q4	I can apply conservation of energy to a charged particle traveling between two charged plates to compute the particle's deBroglie wavelength.
	Q4	I can interpret results of the double-slit experiment for particles by treating them as waves.
	Q4	I can compute the angles for constructive interference in the Davisson-Germer experiment.
Q5	MQ	I can use the mathematics needed to describe the state of a quanton, including complex algebra, the inner product of two complex vectors, probability, and normalization.
	Q5	I can do complex algebra.

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Chapter	Name	Evidence
	Q5	I can compute the intensity required to have a single photon traverse a given distance with a certain probability that there will only be one photon (at any instant) within the given range.
	Q5	I can find the inner product of two complex vectors.
	Q5	I can normalize a complex vector.
Q5, Q6	Qrules	I can recite and apply the "rules of the game" of quantum mechanics.
	Q5	I can look at a series of Stern-Gerlach devices and can predict the probability of an electron being aligned or anti-aligned with a given axis (x, y, z, theta) based on observations of various SG experiments. (Note: this involves understanding how making a measurement affects the electron's state and how recombining electrons of different spins affects the probability of a measurement.)
	Q6	I can write each of the "rules of the game" of quantum mechanics.
	Q6	I can apply the Outcome Probability rule to the spin of an electron.
	Q6	I can apply the Superposition rule to the spin of an electron.
	Q6	I can apply the Time-Evolution rule to the spin of an electron.
	Q6	Given a wavefunction, I can calculate the probability of measuring the position of an electron within a given range Delta x.
	Q6	Given a graph of a wavefunction, I can calculate the probability of measuring the position of an electron within a given range Delta x.
	Q6	I can calculate a normalization constant so that a wavefunction is normalized.
	Q6	I can identify whether a wavefunction is valid or not.
Q7, Q8	Qenergy	I can derive energy eigenvalues for various systems and can relate energy eigenvalues to a spectrum of photons emitted or absorbed.
	Q7	I can derive the energy eigenvalues for a particle in a box and can sketch an energy diagram showing the eigenvalues.
	Q7	I can derive the energy eigenvalues for an electron in a hydrogen atom using the Bohr model.
	Q7	I can derive energy eigenvalues for other hydrogen-like systems.
	Q8	I can use Conservation of Energy to calculate the wavelength (and energy) of a photon emitted or absorbed by a particle in a box.
	Q8	I can sketch a spectrum diagram that shows the photon energies associated with certain transitions for a particle in a box.
	Q8	I can use Conservation of Energy to calculate the wavelength (and energy) of a photon emitted or absorbed by a quantum oscillator.
	Q8	I can derive the energy eigenvalues and the energies of photos emitted and absorbed for a single-electron atom.
Q9	QH	I can describe the set of quantum numbers for a hydrogen atom and can connect these quantum numbers to various representations of the atom, including spectroscopic notation, an energy diagram, and a plot of the real part of the square of the associated energy eigenfunctions.
	Q9	I can determine the possible values of n_r and l for a given value of n for an electron in hydrogen.
	Q9	I can identify n, n_r, and l if given spectroscopic notation.
	Q9	I can relate the number of radial "bumps" to n_r and the number of angular wavelengths to l for a given plot of the square of the real part of the energy eigenfunction for an electron in hydrogen.

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Chapter	Name	Evidence
	Q9	I can write the possible values of m_l for a given l for en electron in a hydrogen atom.
	Q9	I can write the possible values of m_s for an electron in a hydrogen atom.
Q9	Qatom	I can describe how multi-electron atoms are similar to and different from the hydrogen atom and the implications on energy eigenvalues and allowed transitions.
	Q9	I can describe why certain sets of quantum numbers for a hydrogen atom have the same energy, but the same sets of quantum numbers for a multi-electron atom have different energies.
	Q9	I can apply conservation of angular momentum to a transition in a multi-electron atom to determine if that transition is possible or not. I can use this to determine a metastable state.
	Q9	I can draw an energy diagram for the ground-state configuration of a given atom.
Q10	Qpsi	I can write a VPython program to calculate Ψ numerically for a given value of E and graph $\Psi(x)$. I can use this program to find the energy eigenvalues of a system.
	Q10	I can find the energy eigenvalues for a hydrogen atom.
	Q10	I can find the energy eigenvalues for a harmonic oscillator.
	Q10	I can find the energy eigenvalues for a quanton in a well.