Topics in Modern Physics

Course Description:
Topics in Modern Physics is a one-semester course covering major concepts of twentieth-century physics. The course focuses on special relativity, nonrelativistic quantum mechanics, and elementary particle physics. The class also has a project focusing on applications of modern physics.

Instructor:

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- When I am not in class I am usually either in my office or in B116. I usually get to IMSA by 7:30 and leave around 5:00.

Meeting Days, Time and Room(s):
Both period 7 and 8 will meet in B101 on A, B, C, and D days.

Text(s) / Materials:
Serway's *College Physics* will be made available to students to be used as a reference, and Griffiths' *Introduction to Elementary Particles* and Morin's *Introduction to Classical Mechanics* will be on reserve in the IRC as well. Neither text is used explicitly in the class, but both may be helpful as study aids. All material is disseminated electronically, and students are expected to have their computers during class.

Student Learning Objectives:
This course aims to enhance student learning and understanding in special relativity, simple nonrelativistic quantum mechanics, and basic elementary particle physics. This requires exposing and correcting unconscious misconceptions about the nature of space and time, absolute motion, simultaneity, gravity, geometry, position, observation, determinism, probability, causality, the nature of matter, force, nothingness, the role of mathematics, and virtually everything else that most people believe instinctively—and then replacing these misconceptions with a deeper understanding of the behavior of the universe based on experiment. By the end of the course, students should be able to:

- Consider the reference frame of the events in a problem, determine whether it is necessary to consider relativistic corrections, and perform the proper calculations if necessary;
- Understand the importance of eigenstates of quantum-mechanical operators, calculate the probabilities of discrete outcomes in simple systems, and express the

effect of measurement on a wavefunction in terms of eigenstates of noncommuting operators; and
- Explain the basic interactions of elementary particles described in the Standard Model and describe their behavior with Feynman diagrams.
- Know how to research and understand a contemporary particle physics experiment and result.

I.A. Students expected to demonstrate automaticity in skills, concepts, and processes that enable complex thought by:
- Completing assigned problem sets.
- Demonstrating competence on quizzes and exams.

I.B. Students expected to construct questions which further understanding, forge connections and deepen meaning by:
- Analyzing conceptual problems to draw conclusions.
- Discussing problems with peers.
- Modeling systems supported by observations.
- Performing independent research on the final project.

I.C. Students expected to precisely observe phenomena and accurately record findings through:
- Analysis of data in laboratory activities.

I.D. Students expected to evaluate the soundness and relevance of information and reasoning by:
- Drawing conclusions from experimental data .
- Evaluating the soundness of models in light of new information.
- Performing independent research on the final project.

II.A. Students identify unexamined personal assumptions and misconceptions that impede and skew inquiry by:
- Discussing and confronting logical and experimental contradictions that arising from implicit assumptions in scientific thought.

III.A. Students use appropriate technologies as extensions of the mind through use of tablets for completing work and referencing resources by:
- Using computers for information acquisition and analysis of modeled behavior.

III.B. Students recognize, pursue, and explain substantive connections within and among areas of knowledge by:
- Connecting previous concepts in physics to current concepts through problem sets.
- Applying content knowledge to alternative scenarios or new problems on tests.
- Discovering new applications of physics concepts on project assignments.
- Forming connections between different parts of an experiment in the final project.

III.C. Students recreate beautiful conceptions that give coherence to structures of thought by:

- Exploring the development of models (mathematical and conceptual).
- Understanding surprising or counterintuitive results that change our view of the universe.

IV.A. Students construct and support judgments based on evidence by:

- Drawing appropriate conclusions from experimental data.

IV.B. Students write and speak with power, economy, and elegance by:

- Explaining problems and asking questions during group discussions.
- Showing work to clearly communicate problem solutions.
- Writing out problems and their explanations in projects.
- Creating an explanatory poster for the final project.

IV.C. Students identify and characterize composing elements of systems by:

- Breaking down a complicated problem in order to solve it.

V.A. Students identify, understand, and accept the rights and responsibilities of belonging to a diverse community by:

- Dealing with the role of science in the modern world and how to explain it to others.

V.B. Students make reasoned decisions which reflect ethical standards, and act in accordance with those decisions, by:

- Writing about and considering the place of ethics and morality in modern physics.

Teaching and Learning Methodology and Philosophy:
Because modern physics lends itself to few feasible experiments, this course cannot be centered on laboratory activities like many other physics classes. Because the most significant advances in twentieth-century physics were conceptual, rather than experimental, this class focuses on the development of the conceptual framework needed to think about modern physics questions. An emphasis on conceptual, rather than purely computational, problems on the homework and tests facilitates the construction of this framework.

This conceptual framework is essential to doing well in the class, which makes the class competency-driven. Activities such as the practice worksheets and weekly questions contribute to the inquiry-based and problem-centered nature of the class.

Student Expectations:
Students are expected to:

- Arrive to class promptly, sufficiently rested, and with their computers,

    - A student arriving more than a minute after class begins, according to IMSA’s central computer clock, will be marked tardy; a student arriving more than ten minutes late will be marked absent.
- Take notes, as necessary, in class every day,
- Complete all their homework and projects on time,
    - Late assignments will have their point values reduced by 10% each 24-hour period, compounded recursively.
    - Late daily homework will not get higher than 50%.
    - All instances of academic dishonesty will be reported to the Office of Student Life.
- Participate in class discussions and activities,
- Study outside of class, individually or in groups, to understand the material, and ask questions when needed.
    - Most students will find it impossible to understand the material without consulting the instructor or other students outside class.

Assessment Practices, Procedures, and Processes:
There will be weekly exams during the semester, a multi-part semester long project, homework assignments, and a final exam. Homework assignments will not be collected or graded, but will be discussed in class. Your final grade will be based on the following.
55% from weekly tests
30% from the project on particle physics
15% from the final exam

Sequence of Topics and Activities:
(Dates and topics subject to change)

Relativity Unit:
Topics: Reference frames, the theory of relativity, time dilation, length contraction, simultaneity, the Lorentz transformations, paradoxes of relativity, energy and momentum, four-vectors, invariant mass, energy-mass equivalence, the inner product, the equivalence principle, non-Euclidean geometry, gravitational lensing, black holes

Quantum Mechanics Unit:
Topics: Wave motion, frequency and wavelength, the photoelectric effect (with lab), Young’s double-slit experiment (with lab), wave-particle duality, wavefunctions, the Copenhagen interpretation, Dirac notation, eigenvalues and eigenstates, operators, commutation, the Heisenberg uncertainty principle, spin, the particle in a box, entanglement, tunneling

Elementary Particle Physics Unit:
Topics: The Standard Model, path-integral formulation of quantum mechanics, Feynman diagrams, the energy-time uncertainty principle, virtual particles, color and asymptotic freedom, electroweak unification, radioactivity, nuclear fission, nuclear fusion, particle accelerators, particle detectors, ionization detectors, scintillation, cross sections, luminosity, Čerenkov radiation,