GEORGE MASON UNIVERSITY

# Course Approval Form

For approval of new courses and deletions or modifications to an existing course.

*registrar.gmu.edu/facultystaff/curriculum*

**Action Requested:**

[x] Create new course  [ ] Delete existing course
[ ] Modify existing course (check all that apply)
[ ] Title  [ ] Credits  [ ] Repeat Status  [ ] Grade Type
[ ] Prereq/coreq  [ ] Schedule Type  [ ] Restrictions
[ ] Other:

**Course Level:**

[X] Undergraduate
[ ] Graduate

**College/School:** SPACS  **Department:** SPACS
**Submitted by:** Indu Satija  **Ext:** 1274  **Email:** isatija@gmu.edu
**Subject Code:** PHYS  **Number:** 106  **Effective Term:** [X] Fall [ ] Spring [ ] Summer  *Year* 2014

(Do not list multiple codes or numbers. Each course proposal must have a separate form.)

**Title:** Current:
Banner (30 characters max including spaces): The Quantum World
New: The Quantum World: A Continuous Revolution in What We Know and How We Live

**Credits:** (check one) [x] Fixed 3 or  [ ] Variable to

**Repeat Status:** (check one) [x] Not Repeatable (NR)  [ ] Repeatable within degree (RD)  [ ] Repeatable within term (RT)  Maximum credits allowed:

**Grade Mode:** (check one) [x] Regular (A, B, C, etc.)  [ ] Satisfactory/No Credit  [ ] Special (A, B C, etc. +IP)

**Schedule Type Code(s):** (check all that apply) [x] Lecture (LEC)  [ ] Lab (LAB)  [ ] Recitation (RCT)  [ ] Internship (INT)  [ ] Independent Study (IND)  [ ] Seminar (SEM)  [ ] Studio (STU)

**Prerequisite(s):** None

**Corequisite(s):**

**Instructional Mode:**
[X] 100% face-to-face
[ ] Hybrid: ≤ 50% electronically delivered
[ ] 100% electronically delivered

**Special Instructions:** (list restrictions for major, college, or degree;hard-coding; etc.)
For nonscience majors.

**Are there equivalent course(s)?** [ ] Yes [X] No
If yes, please list ______________

**Catalog Copy for NEW Courses Only** (Consult University Catalog for models)

| **Description** (No more than 60 words, use verb phrases and present tense) | **Notes** (List additional information for the course) |
|---|---|
| This course presents quantum physics that revolutionized the 20th Century and continues to evolve. In addition to presenting basic concepts, the course will discuss various applications involving quantum phenomena including quantum computers and quantum teleportation. The course will be a historical journey through the quantum science that many of its founders, such as Einstein, could not accept, and a peek into a possible future.<br><br>Fulfills general education requirement in natural science (non-lab). | |

**Indicate number of contact hours:** Hours of Lecture or Seminar per week: 3  Hours of Lab or Studio:
**When Offered:** (check all that apply) [X] Fall [ ] Summer [ ] Spring

## Approval Signatures

Department Approval ______ Date ______  College/School Approval ______ Date ______

**If this course includes subject matter currently dealt with by any other units**, the originating department must circulate this proposal for review by those units and obtain the necessary signatures prior to submission. Failure to do so will delay action on this proposal.

| Unit Name | Unit Approval Name | Unit Approver's Signature | Date |
|---|---|---|---|
| | | | |
| | | | |

**For Graduate Courses Only**

Graduate Council Member ______  Provost Office ______  Graduate Council Approval Date ______

***For Registrar Office's Use Only:*** Banner______________________________Catalog________________________________

*revised 2/2/10*

## Course Proposal Submitted to the Curriculum Committee of the College of Science

**1. <u>COURSE NUMBER AND TITLE</u>: PHYS 106: The Quantum World: A Continuous Revolution in What We Know and How We Live**

**<u>Course Prerequisites</u>:** None

**<u>Catalog Description</u>:** This course presents quantum physics that revolutionized the 20th Century and continues to evolve. In addition to presenting basic concepts, the course will discuss various applications involving quantum phenomena including quantum computers and quantum teleportation. The course will be a historical journey through the quantum science that many of its founders, such as Einstein, could not accept, and a peek into a possible future.

Fulfills general education requirement in natural science (non-lab).

**2. <u>COURSE JUSTIFICATION</u>:** At present, there exists no non-lab physics general education course.

**<u>Course Objectives</u>:** The course will present exciting developments in physics that continue to bring revolutionary changes, while emphasizing the difficulties, failures, and frustrations that accompanied them. It will also discuss remaining challenges, making it clear that interesting and exciting times are still ahead of us. An important aim is to spread excitement about physics.

**Natural science goal:** The general education natural sciences courses engage students in scientific exploration; foster their curiosity; enhance their enthusiasm for science; and enable them to apply scientific knowledge and reasoning to personal, professional and public decision-making.

**<u>Course Necessity</u>:** To increase the number of non-lab natural science general education courses available to those students who need them.

**<u>Course Relationship to Existing Programs</u>:** This is a physics course for non-science majors.

**<u>Course Relationship to Existing Courses</u>:** Physics now offers three lab natural science general education courses; this will be the first non-lab physics general education course.

**3. <u>APPROVAL HISTORY</u>:** First submission.

**4. <u>SCHEDULING AND PROPOSED INSTRUCTORS</u>:**

**<u>Semester of Initial Offering</u>:** Fall 2014
**<u>Proposed Instructors</u>:** Indu Satija

**5. <u>TENTATIVE SYLLABUS</u>: See below.**

**Quantum Science**
**A Continuous Revolution in what we know and how we Live**
Fall Semester, 2013
Instructor: Indu Satija

**Catalog description:** This course presents exciting developments in quantum physics. More than an historical overview, it addresses the inherent simplicity underlying laws of nature, such non-intuitive phenomena such as quantization and tunneling, and various applications such as NMR, PET, Maglev fast trains, and potentially revolutionary devices such as quantum computers.

Fulfills general education requirement in natural science (non-lab).

**Natural science goal:** The general education natural sciences courses engage students in scientific exploration; foster their curiosity; enhance their enthusiasm for science; and enable them to apply scientific knowledge and reasoning to personal, professional and public decision-making.

## Introduction

Quantum physics powerfully demonstrates the ties between fundamental physics and society. Since its formulation, It clarified the inner workings of atoms and molecules, initiated the drive to miniaturize devices, and led to the discovery of lasers, which have changed everything from the way we think about light to the way we store and communicate information. Quantum physics retains the potential for revolutionary changes beyond our present imagination.

This course offers an opportunity for students to learn about these exciting developments in quantum physics. In addition to an inspiring historical journey through modern science, the course will emphasize the inherent simplicity underlying laws of nature, such as the role of symmetries in important predictions such as the existence of anti-particles. Students will be introduced to quantum phenomena that are non-intuitive, such as Interference phenomena, the dual nature of matter and waves, energy quantization, tunneling, conductors, insulators and topological insulators, and quantization of conductivity and superconductivity.

The course will also highlight various applications of quantum physics, such as NMR, Positron Emission Tomography (PET), superconductivity and Maglev fast trains, superconducting cables, SQUID, quantum-encrypted bank wire transfers, and ring laser gyroscopes. Students will also be introduced to atomic clock and will learn the importance of precision measurements. The course will describe numerous future devices that are under development and possible devices such as quantum computers that may be realized in the future.

## Goals

The course will present exciting developments of physics that continue to bring revolutionary changes while emphasizing the difficulties, failures, and frustrations that accompanied them. It will also discuss remaining challenges, making it clear that the interesting and exciting times are still ahead of us. An important aim is to spread excitement about physics. For students seeking intellectual challenges, this course will make it clear that they need a very little formal training to do research in physics.

**CLASS FORMAT:** Lecture, with discussion and quizzes

Reading assignments and preparation instructions will be posted on-line before every class meeting. Questions and debate will be encouraged in class, but with the firm expectation that these will be conducted with civility and respect for differing ideas, perspectives, and traditions.

**Week I** :The Classical Picture (before 1900)—Wave or Particle:
Particles are characterized by mass, charge, velocity; waves are characterized by frequency, wavelength, speed of propagation, and shape

Examples of different types of waves
Interference phenomena that distinguish particles and waves

Microscopic World of Atoms: Planetary Model of the Atom

Modern Science (after 1900)—Wave-Particle Duality

**Week II**: Experiments that prove particle aspects of light

Experiments proving electron is a particle, and also a wave; similar experiments with other particles

**Week III** Discovery of X-rays and 1901 Nobel prize
Nature of X-rays are just like light waves and how they contributed to establishing particle nature of light

**Week IV**: Stability of the planetary model of the atom; the Bohr model of the Atom.

**Week V**: Energy quantization and its consequences

**Week VI**: The simplicity of the equations describing Laws of Nature:
Symmetries and their consequences (conservation laws)

Important discoveries motivated by symmetry arguments

**Week VII and VIII** Laying the foundation of quantum theory: a discussion based on readings from Nobel prize lectures and scientific biographies

**Week IX:** Nonintuitive quantum phenomena (tunneling, radioactivity, the quantum Hall effect, for example) and applications

**Week X:** The discovery spin and nuclear magnetic resonance, and consequent applications

**Week XI**: Physics at extremely low temperature, and its applications

**Week XI:** Contemporary research and future applications

The time-lag between discovery and applications

**Week XII:** Quantum devices and how they impact life; the importance of precision measurement

**Week XIII:** Nobel prizes of the last quarter-century [liquid crystals (1991, de Gennes); laser cooling (1997, Philips); integrated circuits (2000, Kilby); , Bose-Einstein condensates (2001 Cornell, Ketterle, Wieman); quantum logic gates (2012, Wineland)]

**Week XIV:** Open Challenges

Grand unification, Majorana fermions, dark matter, many-body quantum systems,   and much more

## Instructor and Contact Information

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## Resources (Currently, there is no single book that covers the various topics proposed here):

(1) A set of lecture notes will be prepared and posted on-line
(2) Nobel Lectures can be found at: http://www.nobelprize.org/nobel_prizes/physics/laureates/
(3) Additional WEB resources can be found at, for example:

http://www.scientificamerican.com/topic.cfm?id=quantum-physics
http://www.newscientist.com/article/dn4914-entangled-photons-secure-money-transfer.html
http://www.nature.com/news/quantum-dots-go-on-display-1.12216

(4) Recommended Books:

(a) " It Must Be Beautiful: Great Equations of Modern Science" by Graham Farmelo
(b)  "Controlling the Quantum World: Science of Atoms, Molecules and Photons", Physics 2010, The National Academies Press

## Grading

***Grading will be based on short quizzes, class presentations, and essays***

1. Weekly Quizzes (25%):   True-false and multiple choice format, to check comprehension of recently covered material
2. Weekly Homework Assignments (25%):  Activities designed to promote conceptual understanding
3. Two Five-Page Essays and In-Class Presentations (25%):  I) Read and discuss Nobel lecture, explicating the physics and what you found inspiring; ii) Speculate on the impact of a new quantum device and how it might change the way we live
4. Group Presentation (25%):  Based on the popular literature about a recent research breakthrough in quantum phenomena, describe the discoveries, how were they discovered, and what applications are evolving from them