QUANTUM MECHANICS AND POPULAR PHILOSOPHY

Chem 1911W Freshman Seminar (Writing Intensive)
Fall 2019, 2 credits
3:35 - 5:15 PM Wednesdays, 111 Smith Hall

Instructor - Doreen Leopold, dleopold@umn.edu, (612) 626-2047
Office hours by appointment

One may argue about its causal role in these matters, but there is no doubt that the language of quantum mechanics has provided a powerful new set of metaphors with which to express our understanding of ourselves and our place in the overall scheme of things. We will begin with an introduction to some of the basic ideas of quantum mechanics, including the uncertainty principle and wave/particle duality, and discuss some of the quantum paradoxes that highlight the counter-intuitive nature of these concepts. During the second half of the semester, in students' class presentations on topics of their choice, we will explore the reflections of these ideas in diverse areas. In previous semesters, these have included topics in philosophy, psychology, parapsychology, religion, literature, and the arts, as well as in physics, chemistry, biology, and technology.

Goals: In this course you will

a) Become better acquainted with other students, a faculty member, and the U of M
b) Get some practice writing and teaching
c) Gain a familiarity with some of the basic ideas of quantum mechanics
d) Explore the reflections of these ideas in a variety of other areas and in your personal experience
e) Enjoy yourself!

Requirements: (details on the next page)

a) Attend all classes
b) Participate actively in discussions
c) Do assigned readings and prepare questions
d) Pass weekly short quizzes and longer final quiz
e) Write two papers (at least 2,500 words each)
f) Teach part of a class

Daily schedule:

Short quiz on assigned reading and discuss answers
Questions/comments on this week's readings, previous material, etc.
Presentation/discussion by Doreen and/or students
Plan for next week

Books available in bookstore (required):

- "Quantum: a Guide for the Perplexed", by Jim Al-Khalili (2003)
- "The Tao of Physics: an Exploration of the Parallels between Modern Physics and Eastern Mysticism", by Fritjof Capra (1975; 4th edition, 2000)

Grading:

The following 4 categories will each contribute to the course grade:

- quizzes (including final quiz, 10%) 20%
- class participation 10%
- class presentation 20%
- writing assignments 50% (25% each)

A grade of "satisfactory" will be equivalent to a B.

Quizzes:
Each class will begin with a short (10 minute) quiz on the assigned reading (typically under 50 pages).
The purpose of these quizzes is to encourage students to do the assigned reading before coming to class.
There will be 3 or 4 questions, and it will be easy to answer them satisfactorily if one has done the reading.
The quizzes are open-notebook; that is, students can consult their own notes (but not other people's notes or the assigned reading).
There will also be a longer, approximately 60-minute final quiz during the next-to-last week of class (***Wed. Dec. 4***).
This quiz will mainly focus on the quantum mechanics material covered during the first half of the semester.
The last two pages of this syllabus (constants, conversions, and equations) can also be used during the quizzes.

Student presentations:
The topic and brief description of each student's planned presentation, to occur during weeks 10-12 (***Nov. 6 - Nov. 20***), should be ready at the start of class on ***Wed. Oct. 2***. (Students who prefer to get a head start on their papers can submit their topics earlier.) We will review these together and determine everyone's presentation dates. One week before the presentation, the presenter should provide a reading assignment for the class from one or more of our texts, from online sources, or from other materials that we can make available on our class website and/or email to everyone.

The presenter should prepare a 15-20 minute presentation, and be ready to lead a 15-20 minute class discussion. The presentations should be interesting and informative. For the discussion portion, the presenter should prepare questions to supplement (if necessary) those posed by the students, and/or a class activity.

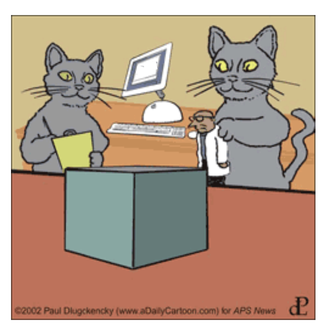
Writing assignments:
Each student will also prepare two papers of at least 2,500 words each.
The first of these must be submitted on or before ***Wed. Oct. 16***, and will be returned in class the following week with comments.
The revised version of this paper is due ***Wed. Nov. 6***.
The second paper is due on or before ***Wed. Dec. 4***.
One of these papers may be on your presentation topic. In general, the second paper will be on a significantly different topic than the first paper, rather than an extension of the same topic.

Students' papers should be on topics discussed in class, in our texts, or on related subjects. *At least 500 words of each paper should provide a scientifically accurate discussion of one or more aspect(s) of quantum mechanics that is/are relevant to the main topic of the paper.* At least one of the two papers must be a research paper that cites at least 5 books and/or articles in high-quality journals. Books and journal articles may be obtained through Walter Library (next to Smith Hall) and other U of M libraries, through which students also have access to an extensive selection of electronic journals, as will be described by librarian Meghan Lafferty in our library workshop on ***Wed. Sept. 25***.

Some additional guidelines on writing papers:
1. You should pay attention to the writing style, use of correct grammar, spelling and punctuation, and the citation of references at appropriate points throughout your paper. See our class website for guidelines on formatting citations and references.
2. Your papers should be new, rather than being modifications of papers you have previously written for another purpose.
3. "Avoiding Plagiarism": see the excerpt by M. Roig, posted on our website, for guidelines for acceptable paraphrasing.
   Plagiarism is "scholastic dishonesty" and may result in academic sanctions, including a failing grade.
   For more information on scholastic dishonesty, see: https://cse.umn.edu/r/scholastic-integrity/
   Also see the U of M Conduct Code posted on our website (plagiarism is described on p. 2)

Class website (Canvas)
There are several interesting items posted on our class' Canvas website, including "Articles and Interesting Links" (such as Feynman's "Quantum Behavior" chapter from *Lectures on Physics*, excerpts from Silberberg's "Chemistry" textbook, and the Hitachi movie of a double-slit experiment with electrons), links to library resources, and other materials. With their permission, students' papers will also be posted there near the end of the semester. To access our web site:

- Connect to http://myu.umn.edu, log in,
  click on the "My Courses" tab and select the Canvas link for Chem 1911W.
- Or, go directly to the Canvas website for our class:
  https://canvas.umn.edu/courses/144669



For help with computer-related problems, you can call the Technology Helpline at 1-HELP on campus, or (612) 301-4357.

Week	Date	Topic	Reading Due this Week	Presenter(s)
	Part I	**Some Basic Ideas of Quantum Mechanics**		
1	Sept. 4	Introduction; 2-Slit Experiment	---	DGL
2	Sept. 11	Wave-Particle Duality and the 2-Slit Experiment, continued; Nature of Light	• Al-Khalili 6-25, 79-91(top) • Silberberg (8^{th} Ed., posted) Sect. 7.1, pp. 295-299 • Feynman Chap. 1 (posted)	
3	Sept. 18	De Broglie Wavelength Uncertainty Principle	• Al-Khalili 47-51, 68-69 • Capra 17-25, 144-160, 191-194 • Silberberg Sect. 7.3, pp. 310-313	
4	**Sept. 25**	***Walter Library Workshop: Use of On-Line Resources***	https://www.lib.umn.edu/walter	*Meghan Lafferty (Walter 310)*
5	**Oct. 2**	***Submit topic(s) for presentation & first paper*** Blackbody Radiation Photoelectric Effect Planck's Constant	• Al-Khalili 27-44 • Capra 45-72 (top) • Silberberg Sect. 7.1, pp. 299-302	
6	Oct. 9	Quantized Energy Levels; Hydrogen Atom: Spectrum, Bohr Model	• Al-Khalili 44-47 • Capra 130-143 • Silberberg Sect. 7.2, pp. 302-309	
7	**Oct. 16**	***First paper due*** Schrödinger Equation Wave Function (ψ) Quantum Numbers	• Al-Khalili 53-68, 72-75	
8	**Oct. 23**	***First paper returned with comments*** Nonlocality, Entanglement EPR Paradox Schrödinger's Cat	• Al-Khalili 91-120 • Capra 303-313	
9	Oct. 30	Measurement Problem Decoherence Copenhagen Interpretation de Broglie - Bohm Interpretation Many-Worlds Interpretation	• Al-Khalili 121-153	

Week	Date	Topic	Reading Due this Week	Presenter(s)
Part II Student Presentations				
10	**Nov. 6**	***Revised version of first paper due*** • •		
11	Nov. 13	• •		
12	Nov. 20	• •		
	Nov 27	***No class (day before Thanksgiving)***		
13	**Dec. 4**	***Second paper due*** ***Final Quiz (1 hour)***		
14	**Dec. 11**	***End-of-semester celebration*** ☺		

Some useful constants and conversions:

h	Planck's constant	6.6×10^{-34} Joule seconds
c	speed of light in vacuum	3.0×10^{8} meters / second = 3.0×10^{10} centimeters / sec
m_e	mass of an electron	9.1×10^{-31} kilogram
m_p	mass of a proton	1.7×10^{-27} kilogram
e	elementary charge	1.6×10^{-19} Coulomb (same magnitude for electron, which is negatively charged, and proton, which is positively charged)

Units of energy

1 J (Joule) = kilogram meter^2 / second^2 = $kg \cdot m^2/s^2$

$J = V \cdot C$ (1 Joule = 1 Volt *x* 1 Coulomb)

1 eV (electron volt) = 1.6×10^{-19} Joule (corresponds to 8066 cm^{-1})

wavenumbers (cm^{-1}) = inverse centimeters = E / (h c)

where E is the energy in Joules,

h in Joule seconds, c = speed of light = 3.0×10^{10} cm/s

Units of distance

centimeter (cm) = 10^{-2} meter

nanometer (nm) = 10^{-9} meter

Angstrom (Å) = 10^{-10} meter

Unit of mass

1 kg (kilogram) = 1,000 g (grams)

Some useful equations:

$\nu = c / \lambda$ for light, relationship between its frequency (ν, cycles/sec = hertz) and wavelength (λ, meters), where c is the speed of light (3.0×10^8 m/s)

$E_{photon} = h\,\nu$ energy of one photon of light of frequency ν (cycles/sec = hertz)

$p = m\,v$ momentum (p) = mass (m) x velocity (v) (does not apply to light)

$\lambda = h/p$ de Broglie wavelength of a particle with momentum p = mv (does not apply to light)

$\Delta x\, \Delta p \geq h$ Heisenberg Uncertainty Principle, where

Δx is the uncertainly in the particle's position

$\Delta p = m\,\Delta v$ is the uncertainty in the momentum of a particle of known mass, for which the uncertainty in the velocity is Δv

Kinetic energy (KE) = $\frac{1}{2} mv^2 = p^2 / (2m)$ (where the particle's momentum is $p = m\,v$)

$= e \cdot V$ for an electron (with charge of magnitude e, in Coulombs) accelerated through a potential difference V (in Volts)

$h\nu = \phi + \frac{1}{2} m_e v^2$ KE = $\frac{1}{2} m_e v^2 = h\nu - \phi$ Photoelectric effect:

$h\nu$ is the energy of one photon of frequency ν (cycles/sec = hertz)

ϕ is the work function of the metal

KE = $\frac{1}{2} m_e v^2$ is the kinetic energy of a photoelectron moving at speed v (m/s)

H (hydrogen) atom energy levels (in eV) relative to E = 0 for separated nucleus (proton) and electron (where quantum number n = 1, 2, 3, ... ∞)

in units of eV and Joules $E\text{ (eV)} = -13.6\text{ eV} / n^2 = -2.18 \times 10^{-18}\text{ J} / n^2$

in units of cm^{-1} = E / hc $\tilde{\nu}\,(\text{cm}^{-1}) = -109{,}678\ \text{cm}^{-1} / n^2$

note conversion: $109{,}678\ \text{cm}^{-1} / (8066\ \text{cm}^{-1}/\text{eV}) = 13.6$ eV

Rydberg formula for hydrogen (H) atom, where $n_1 < n_2$ (quantum numbers)

in units of eV and Joules $\Delta E\text{ (eV)} = 13.6\text{ eV}\,(1/n_1^2 - 1/n_2^2) = 2.18 \times 10^{-18}\text{ J}\,(1/n_1^2 - 1/n_2^2)$

in units of cm^{-1} = E / hc $\tilde{\nu}\,(\text{cm}^{-1}) = 109{,}678\ \text{cm}^{-1}\,(1/n_1^2 - 1/n_2^2)$

Spectroscopy: requirement for a photon to be absorbed or emitted by a system

$E_{photon} = \Delta E_{system}$ where $E_{photon} = h\,\nu$ for light of frequency ν

ΔE_{system} = difference between two energy levels of the system