QUANTUM MECHANICS AND POPULAR PHILOSOPHY

Chem 1911W Freshman Seminar (Writing Intensive)
Spring 2023   2 credits

Wed. and Fri. at 10:10 - 11:00 AM in Smith 121
Instructor: Doreen Leopold

Office - Smith 211, 6-2047, dleopold@umn.edu

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 wave/particle duality and the uncertainty principle, and discuss some of the quantum paradoxes that highlight the counter-intuitive nature of these concepts. For these topics, we will be guided by "Quantum: a Guide for the Perplexed" by Al-Khalili. Through students' class presentations and the topics explored in our other two books, we will discuss the reflections of these ideas in Eastern religions ("Tao of Physics" by Capra), in psychology and philosophy ("The Quantum Self" by Zohar), and in other areas selected by the students.

Goals: In this course you will …

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

Requirements:

a) Attend all classes (or request an excused absence before class if you cannot attend)
b) Participate in discussions
c) Read the assigned items, take notes, and prepare questions and comments for class discussions
d) Pass (most of) the in-class quizzes (to be given once or twice a week during the first 7 weeks)
e) Write two original papers of at least 2,500 words each
f) Do a class presentation about your chosen topic and lead a discussion

Books (Required):

- "Quantum: a Guide for the Perplexed", by Jim Al-Khalili (eBook or paperback)
- "The Tao of Physics: an Exploration of the Parallels between Modern Physics and Eastern Mysticism", by Fritjof Capra (eBook or paperback)
- "The Quantum Self: Human Nature and Consciousness Defined by the New Physics", by Danah Zohar (paperback)

(At the U of M Bookstore, the total cost for these 3 items is between $33 and $42, depending on the format purchased.)

Weekly Schedule: Our class meets twice a week, on Wednesdays and Fridays, from 10:10 to 11:00 am.

- Start with a short (10-minute) quiz on the assigned reading and previous material, go over answers
- Questions and comments on this week's readings, previous material, etc.
- Presentation (by Doreen or students) and class discussion
- Plan for the next class

Class Canvas Website:

There are several useful items on our class Canvas website:

- PowerPoint notes used in class during the first 7 weeks of the semester (on the "Home" page)

In the "Modules" section:

- Writing resources (writing and referencing style, avoiding plagiarism)
- Library resources
- "Articles, Book Excerpts, Videos, and Other Online Resources"
  (includes assigned reading from Feynman and Silberberg/Amateis book chapters)
- Students' papers and presentation slides (if permission is given to share)

To access our Canvas website:

- Connect to http://myu.umn.edu, log in,
  click on the “My Courses” tab and select the Canvas link for Chem 1911W.
- Or, enter this link into your web browser: *https://canvas.umn.edu/courses/354820*

For help with computer-related problems: Technology Helpline can be reached at 1-HELP on campus, or (612) 301-4357.

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

• Quizzes	20%	
• Attendance and participation in discussions	20%	
• Presentation	20%	
• Writing assignments (two papers, final versions)	40%	(20% each)

Quizzes:

Most classes during the first half of the semester will begin with a short (10-15 minute) quiz on the assigned reading and sometimes also on material discussed in our previous classes.
There will be 3 or 4 questions, and it will be straightforward to answer them correctly if one has done the reading and kept up with class discussions.

The ***weekly quizzes*** are ***open-note***; that is, students can consult their own notes (but not other people's notes, the assigned reading or the posted lecture slides). The last two pages of this syllabus (***constants, conversions, and equations***) can also be used during the weekly quizzes. It is helpful to bring a calculator.
The quizzes will contribute a total of 20% of the course grade.
We will *not* have an exam during finals week.

Reading:

Reading assignments for the first half of the semester (up to Spring break) are listed by date on p. 6 and by source on pp. 8-9. These total about 250 pages (about 40 pages a week) and include excerpts from our three books and from some other sources posted on our Canvas website.
Readings during the 2nd half of the semester will be determined by students' choices of presentation topics.

Writing Assignments:

Each student will also write two papers of at least 2,500 words each.
A **draft** of the **first paper** is due on or before week 6 ***(Fri. Feb. 24)*****,** and will be returned before Spring break with comments and suggestions for improvements, if needed.
The **revised version** of the first paper is due on or before week 9 ***(Fri. Mar. 24)***.
The **second paper** is due on or before week 13 ***(Fri. Apr. 21)***. Submission of a first draft for feedback a week or two before that date is not required, but is welcomed.
The two papers will each contribute 20% of the course grade (40% total).

At least one of these should be written as a **research paper**, including citations at appropriate points within the text and a properly formatted list of references.

• A list of suggested topics for students' papers will be posted on our Canvas site (under "Modules"). Good starting points for papers also include portions of our 3 books not covered earlier in the semester.
• At least **300 words** (about one page) 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.
• Papers written in a research style (as contrasted with creative writing, for example) should cite at least three articles in peer-reviewed scientific journals, in addition to the other references cited (e.g., websites). U of M students have access to an extensive selection of electronic journals, encyclopedias and other resources, as will be described by librarian Meghan Lafferty during our **library workshop on Wed. Feb. 8.**
• Close attention should be paid to maintaining a professional writing style, including the use of correct grammar, spelling and punctuation, citation of references at appropriate points throughout the paper, and a properly formatted reference list. Our class Canvas site (under "Modules") provides some useful "Writing Resources", and we will also discuss these in class.
• Students should not submit papers that they (or, of course, others) have written for other courses. The writing should be the student's original work, except for direct quotes which are shown within quotation marks and are appropriately cited. It is important for this (and future) classes to strictly avoid plagiarism, which may take the form of closely paraphrasing extended excerpts of writing (or audio transcriptions) from other sources, even if these are cited. One should not use chatbots such as "ChatGPT" to aid in writing.
Transgressions of these guidelines will be considered as academic dishonesty (see item #3 on p. 4).

Student Presentations:

Student presentations will take place during weeks 8-14 (***Mar. 15 - Apr. 26***).
We will organize the presentation schedule during our class on ***Wed. Mar. 1***.
Students generally choose to give their presentation on the topic of their first or second paper.
The presenter should prepare a presentation of about 15 min., and then lead a class discussion.
For the discussion, the presenter should prepare questions to supplement those posed by the other students.
The presentation can be supplemented by YouTube (or other) videos about the chosen topic.
The class presentation will contribute 20% toward the course grade.

Additional Links to Recommended U of M Syllabus Policy Statements

WEBPAGE: https://policy.umn.edu/education/syllabusrequirements-appa

1. Academic freedom and responsibility: Students are encouraged to develop the capacity for critical judgment and to engage in a sustained and independent search for truth. For more on academic freedom, see:
https://regents.umn.edu/sites/regents.umn.edu/files/2019-09/policy_academic_freedom_and_responsibility.pdf

2. Student conduct code:
https://regents.umn.edu/sites/regents.umn.edu/files/2020-01/policy_student_conduct_code.pdf

3. Avoiding scholastic dishonesty:
https://communitystandards.umn.edu/avoid-violations/avoiding-scholastic-dishonesty

Scholastic Dishonesty is discussed under CSE's scholastic policies and is defined in the University Student Conduct Code as follows:

"Scholastic Dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis."

Academic dishonesty in any portion of the academic work for a course shall be grounds for assigning the student a grade of F (or N) for the entire course.

4. Use of personal electronic devices: https://https://policy.umn.edu/education/studentresp

5. Respecting Intellectual property:

> “Students may not distribute instructor-provided notes or other course materials, except to other members of the same class or with the express (written) consent of the instructor. Instructors have the right to impose additional restrictions on course materials in accordance with copyright and intellectual property law and policy. Students may not engage in the widespread distribution or sale of transcript-like notes or notes that are close to verbatim records of a lecture or presentation."

6. Grading: http://policy.umn.edu/education/gradingtranscripts

7. Makeup work for legitimate absences: http://policy.umn.edu/education/makeupwork

8. Access and disability accommodations: https://diversity.umn.edu/disability/

9. Student mental health and stress management:
To learn more about the range of confidential mental health services available on campus, see: http://www.mentalhealth.umn.edu/

10. Sexual harassment and related topics: The Chemistry Department strives to provide a safe and positive environment for everyone. Please review the policies regarding sexual harassment and related topics:
https://policy.umn.edu/hr/sexharassassault
For support and help please contact the Aurora Center:
http://aurora.umn.edu

11. Diversity, equity, inclusion: We welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability, and other visible and nonvisible differences to this course. Instructors, teaching assistants, and peer students are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class. This is in agreement with university policy:
http://regents.umn.edu/sites/regents.umn.edu/files/policies/Equity_Diversity_EO_AA.pdf

12. Department of Chemistry Diversity, Equity and Inclusion (DEI) Committee:
Collaboration among people of all cultures and backgrounds enhances our experiences and contributes to excellence in teaching, learning, and research. We strive for a climate that celebrates our differences and strengthens our Department by embracing and working to increase diversity, equity, and inclusion. For more information about our departmental efforts and upcoming activities, see:
https://cse.umn.edu/chem/diversity-inclusion

For a list of diversity-related resources, see:
https://sites.google.com/umn.edu/chemintranet/diversity-inclusion/department-initiatives

Schedule for Chem 1911W, Spring 2023 (Quantum Mechanics and Popular Philosophy)

Al-Khalili pages listed first are for the 2012 edition (black and white striped cover), and (pages) shown in parentheses are for the 2003 edition (blue cover).

Week	Date	Topics	Reading for Wednesday	Reading for Friday
	Part I	**Some Basic Ideas of Quantum Mechanics**		
1	Jan. 18, 20	Introduction to Class; 2-Slit Experiment	---	---
2	Jan. 25, 27	Wave-Particle Duality (continued), Nature of Light	• Al-Khalili pp. vii - xi, 1-17 (pp. 6-9, 12-25) • Silberberg Chap. 7 (posted) pp. 295 - 299	• Al-Khalili pp. 66-79 (pp. 80-91) • Feynman Chap. 1 (posted) pp. 1-11
3	Feb. 1, 3	(Wed.) de Broglie Wavelength (Fri.) Uncertainty Principle	• Al-Khalili pp. 37 - 41 (pp. 47 - 51) • Silberberg pp. 310-312 • Capra Chap. 1, pp. 17 - 25	• Al-Khalili pp. 55 - 57 (pp. 68 - 71) • Silberberg pp. 313 • Capra Chap. 3, pp. 45 - 51 • Capra Chap. 13, pp. 191-194
4	Feb. 8, 10	***(Wed.) Walter Library Workshop*** (Fri.) Blackbody Radiation	**Meet in classroom and go to Walter 320** *Meghan Lafferty* www.lib.umn.edu/walter • Capra Chap. 4, pp. 52 - 72	• Al-Khalili pp. 18 - 26 (pp. 28 - 38) • Silberberg pp. 299 - 300
5	Feb. 15, 17	Photoelectric Effect Planck's Constant	• Al-Khalili pp. 27 - 33 (pp. 38 - 44) • Silberberg pp. 301 - 302	• Capra Chap.10, pp. 130-143 • Zohar Chap. 8, pp.107-124 "The Person that I Am: Quantum Identity"
6	Feb. 22, 24	***Fri. Feb. 24: Draft of first paper due*** Quantized Energy Levels, H Atom Spectrum, Bohr Model	• Al-Khalili pp. 34 - 37 (pp. 44 - 47) • Silberberg pp. 302-307	• Capra Chap. 11 pp. 144-160 • Zohar Chap. 9 pp. 125-140 "The Relationships that I Am: Quantum Intimacy"
7	Mar. 1, 3	(Wed.) Schrödinger Equation, Wave Functions (ψ), Quantum Numbers (Fri.) Electron Spin, Periodic Table	***(W) Organize dates for student presentations after Spring break*** • Al-Khalili pp. 42-55, 61-63 (pp. 54-68, 72-75) • Silberberg pp. 314-315	***(Fri.) Draft returned with suggestions*** • Silberberg (Chapter 8) pp. 332, 335 - 336, 341 • Zohar Ch.10 pp. 141-153 "The Survival of the Self: Quantum Immortality"
	Mar. 6 - 10	*Spring Break*		

Part II Student Presentations			
8	Mar. W 15 F 17		
9	Mar. W 22 F 24	***Fri. Mar. 24: Revised (final) version of first paper due***	
10	Mar. W 29 F 31		
11	Apr. W 5 F 7	***Fri. Apr. 7: Draft of second paper (welcome but draft submission not required)***	
12	Apr. W 12 F 14		
13	Apr. W 19 F 21	***Fri. Apr. 21: Second paper due (final version)***	
14	Apr. W 26 F 28	***Fri. Apr. 28: End-of-semester celebration***	

Summary of Reading by Source *(same items as on p. 6)*

• **Al-Khalili, "Quantum: A Guide for the Perplexed"**
Listed here (in parentheses) are the pages in the original 2003 edition (paperback with blue cover) and in the 2012 edition (cover with black and write stripes).

(Blue cover) 2003	**B&W striped** 2012		
Introduction *(all)*			
(6-9)	vii - xi		Week 2
Chapter 1: Nature's Conjuring Trick *(all)*			
(12-25)	1 - 17	Two-Slit Experiment	Week 2
Chapter 2: Origins *(all)*			
(28 - 38)	18 - 26	Blackbody Radiation, Planck's Constant	Week 4
(38 - 44)	27 - 33	Photoelectric Effect, Einstein	Week 5
(44 - 47)	34 - 37	Bohr Model of the Hydrogen Atom	Week 6
(47 - 51)	37 - 41	DeBroglie Wavelength "A French Prince Rides In"	Week 3
Chapter 3: Probability & Chance *(excerpts)*			
(54 - 68)	42 - 55	Schrödinger Equation, Wavefunctions, Quantum Numbers, Unpredictability	Week 7
(68 - 71)	55 - 57	Heisenberg's Uncertainty Principle Silberberg	Week 3
(72 - 75)	61 - 63	Golden Years of Quantum Mechanics	Week 7
Chapter 4: Spooky Connections *(excerpts)*			
(80 - 91)	66 - 79	Superposition, the 2-Slit Trick "explained", Particle Interferometers (until section subtitled "Nonlocality")	Week 2

• **Silberberg & Amateis "Chemistry"** (8th Ed., excerpts posted on Canvas)

Chapter 7, "Quantum Theory and Atomic Structure" *(excerpts)*

295 - 299	Waves (frequency ν, wavelength λ, amplitude) Constructive and destructive interference of waves Light as electromagnetic waves Regions of the electromagnetic spectrum Speed of a wave ($v = \nu \lambda$; for light, $c = \nu \lambda$)	Week 2
299 - 300	Blackbody radiation and Planck's constant, *h*	Week 4
301 - 302	Photoelectric effect, Einstein's interpretation of light as particle-like $E = h \nu$ = energy in a photon of light of frequency ν	Week 5
302 - 303	Hydrogen atom spectra and the Rydberg equation	Week 6
303 - 307	Bohr model of the H atom spectrum, H atom electronic states, energy levels	
310 - 312	de Broglie wavelength, wave-particle duality of matter	Week 3
313	Heisenberg's uncertainty principle	Week 3
314 - 315	Schrödinger equation, quantum model of the atom	

Chapter 8, "Electron Configuration and Chemical Periodicity" *(excerpts)* Week 7

332	Electron spin
335 - 336, 341	Quantum Mechanical Model and the Periodic Table

• **Feynman, "Lectures on Physics" (1965)** (book excerpt posted on Canvas)

1-11	Chapter 1 *(all)*, "Quantum Behavior"	Week 2

Summary of Reading, by Source (continued)

- **Capra, "Tao of Physics" (1975)**

Chapter 1, "Modern Physics: a Path with Heart?" *(all)*	pp. 17 - 25	Week 3
Chapter 3, "Beyond Language" *(all)*	pp. 45 - 51	Week 3
Chapter 4, "The New Physics" *(excerpt)* (until the paragraph beginning "Tendencies to exist...")	pp. 52 – 72	Week 4
Chapter 10, "The Unity of All Things" *(all)*	pp. 130 - 143	Week 5
Chapter 11, "Beyond the World of Opposites" *(all)*	pp. 145 -160	Week 6
Chapter 13, "The Dynamic Universe" *(excerpt)* (until the paragraph beginning "In physics, we recognize...")	pp. 189 - 194	Week 3

- **Zohar, "Quantum Self: Human Nature and Consciousness Defined by the New Physics" (1990)**

Chap. 8, "The Person that I Am: Quantum Identity"	pp.107-124	Week 5
Chap. 9, "The Relationships that I Am: Quantum Intimacy”	pp. 125-140	Week 6
Chap.10, "The Survival of the Self: Quantum Immortality"	pp. 141-153	Week 7

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 $n = 1, 2, 3, \ldots \infty$)

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