Ned Hall Office: Emerson 204
Hours: Wednesday, 2 - 4 (or by appt.) Ph: 495-2486
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Description:

Quantum mechanics has been a staggeringly successful physical theory, one of the crowning achievements of 20th century science. It's also rather bizarre—bizarre enough to lead very intelligent and otherwise sensible people to make such claims as that the universe is perpetually splitting into many copies of itself, that conscious minds have the power to make physical systems "jump" in unpredictable ways, that classical logic stands in need of revision, that there is no objective world, and much, much more.

In this course, we intelligent and sensible people will take a sober look at these and other alleged implications of quantum mechanics, as well as certain stubborn problems that continue to trouble its foundations. We will do this partly because quantum mechanics is seriously cool, and deserves to be studied as such; and partly because studying it will give us an excuse to examine some important philosophical questions about science. (See below.)

Why is this a philosophy course?

The blunt part of the answer is that a course like this needs *some* home, and it typically won't find it in a physics department. The more refined part of the answer is that studying quantum mechanics "philosophically" will give us an opportunity to examine, in a sharp way, several intriguing questions about science. We'll target these four:

- What is *probability*, in the physical world?
- Is it the proper aim of science not merely to develop theories that precisely and accurately *predict* phenomena, but to develop theories that also *explain,* or *yield understanding of*, those phenomena?
- How (if at all) can a rational choice be made between theories that make exactly the same predictions?
- Must an acceptable physics present a clear, intuitively comprehensible picture of what the micro-world is like, and of how the macro-world 'emerges' from it?

Reasons to take this course:

You've heard crazy things said about quantum mechanics, or with quantum mechanics cited as their justification; you're wondering whether they're true. You've taken some QM already, but found it utterly baffling, for conceptual and not merely mathematical reasons. You're curious about the philosophical questions mentioned above. You care about the fundamental structure of reality. You appreciate Ned's home-baked cookies. Any or all of these (well, okay, maybe not the last one) are good reasons to take this course.

Reasons to be worried, and not to be worried, about taking this course:

There's really just one reason to be worried: you're seriously math-phobic (and the best option—which is that you get cured of this phobia—somehow isn't available). You will need to learn some basic linear algebra (if you don't already know it); there's no way around this, given that we want to treat conceptual and philosophical questions about quantum mechanics in an intellectually responsible manner. On the bright side, what you need to learn isn't really that daunting. (There's no calculus: no integrals, no differential equations, no fourier transforms, etc.) If you've come across vectors before, and know some very basic trigonometry, and are willing to expend some extra effort (especially at the beginning of the course), you should be fine.

Note, finally, that the course assumes *no prior exposure* to quantum physics. It helps, to be sure—but not so much that you need to worry, if you don't have it. After all, *one* way that this course is intended to function is as a kind of (highly non-standard) *introduction* to quantum physics.

It should perhaps be mentioned that, judging from comments from students in the past, this course is a fair amount of work. But fun. Waaay fun.

Readings:

The required text for the course is Tim Maudlin's *Philosophy of Physics, Vol. 2: Quantum Theory*. Maudlin's *Quantum Non-locality and Relativity* is highly recommended. Additional readings (usually articles, and always posted on the course web site) will be assigned at various points throughout the course.

The material is, in most cases, trickier than meets the eye; read it at least *twice*. (And don't be worried if it *still* doesn't make perfect sense – that's what we're here for.)

Expectations:

You will have **almost-weekly homework assignments**, which will sometimes involve 2-5 pages of writing (1 page = 300 words), sometimes take the form of problem sets, and sometimes mix these formats. (In addition, one of the assignments will be in the form of an in-class quiz.) There will be 7 such assignments in all. Please note that you should plan to submit these assignment electronically, to the course dropbox.

You will also engage in a **collaborative project** with some of your classmates, designed around one of the four philosophical questions listed above. We'll provide more details on this project during the third or fourth week of class.

In the second week, we will hand out a **linear algebra worksheet**; this will be due at the end of the fourth week. For those of you suffering math phobia, don't worry: it will be fairly easy, and we will offer *lots* of help with it – in office hours, and in special sections set aside to review/explain/clarify the math.

There will be take-home – and highly comprehensive – **final exam**, due at the end of reading period. We're planning to hand it out no later than at the end of spring break.

There will be **weekly discussion sections**, (days/times TBA), starting the second week of class. Attendance is mandatory.

Here are some more expectations:

We will occasionally hand out, at the beginning of class, an extremely short, ridiculously-easy-if-you've-done-the-reading (REYDR™) quiz. It will take 5 minutes. Unless you haven't done the reading, in which case, as my son Galen once put it, you're … Never mind. I can't print that.[1]

By noon each Sunday (starting at the end of week 2 – i.e., Sunday, Feb. 4), you will need to email us a short (approximately 150 words) **reaction to the week** that just happened. What confused you (either in the readings, or in class discussion)? What inspired you? What topics/questions struck you as urgently in need of more discussion? We want to know. We will use your collective reactions as a way to regularly take the pulse of the class, and to adjust what we're doing accordingly. Finally, this email should *include* at least one well-posed question that you would like to see taken up in the discussion section for the upcoming week. (We've posted a handy template for these weekly reactions, on the web site.)

[1] "f***ed" - Galen

You **have to come to class**. That's right: *every* class (including the discussion section). Unless (i) you're deathly ill[2] (in which case, please notify us by email before or shortly after the class time); or (ii) you've cleared your absence with us ahead of time. Also, for the purpose of this course, "coming to class [or section]" means "showing up at the *beginning* of class [or section], and staying for the duration".

You may not use electronic devices in class, of any kind, unless you have an astoundingly compelling reason that you convey to us ahead of time. (There will be slides and/or a script for each class, so you will not be under pressure to take comprehensive notes. And anyway, there's some halfway decent psychological literature that suggests that taking notes by hand is far better than typing them, with respect to comprehension.)

Hopefully, by now, you get the picture: If you opt to take this class, we expect from you a fairly serious and sustained commitment to it. At the same time, you should expect an equal commitment from us. Our job is to help make you better – much better – at reading, thinking about, discussing, and producing your own philosophical material. That means, among other things,

- giving you prompt feedback on your work;
- creating a stimulating but welcoming environment in the classroom;
- making it easy for you to draw on our help, outside of class.

So think of this as a **contract**. We want this class to be inspiring, captivating, stimulating, etc. That's our part of the contract. Your part is to *show up*, in every relevant sense of that term.

The discussion sections:

The weekly discussion sections have, as their primary reason for being, these four things:

1. understanding complicated philosophical texts;
2. breaking down arguments and locating their weak points;
3. formulating philosophically interesting questions;
4. working together to try to develop good (not necessarily *correct*) answers to such questions.

They are not places to clear up confusions about the math, or other narrowly technical issues; that's what Ned's and Anya's office hours (and the SOLACE – Scads Of Linear Algebra Concepts Explained – sections; see below) are for.

[2] Okay, slightly-less-than-deathly-ill counts, too.

Grading:

Let's start by reminding ourselves, shall we, of the standards we *claim* to enforce here at Harvard (I'm not making these up – check the relevant handbooks!):

A, A– Earned by work whose excellent quality indicates a full mastery of the subject and, in the case of the grade of A, is of extraordinary distinction.

B+, B, B– Earned by work that indicates a good comprehension of the course material, a good command of the skills needed to work with the course material, and the student's full engagement with the course requirements and activities.

C+, C, C– Earned by work that indicates an adequate and satisfactory comprehension of the course material and the skills needed to work with the course material and that indicates the student has met the basic requirements for completing assigned work and participating in class activities.

D+, D, D– Earned by work that is unsatisfactory but that indicates some minimal command of the course materials and some minimal participation in class activities that is worthy of course credit toward the degree.

Our little corner of the world would be a much *better* little corner if we (the faculty) uniformly enforced just these standards. (Well, the "extraordinary distinction" stuff is a bit much, but you get the idea.) In this course, we will, in fact, follow them. But – rather more importantly – we also intend (i) to make it as clear as possible to you what A-level work looks like; and (ii) to help you as much as possible reach the point where you can produce it.

Here's the plan.

You can earn up to 100 points in this course, as follows:

Each of the 7 short assignment is worth 9 points. To make it easy for you to keep track of how you're doing, we will score the assignments on a scale of 1 to 9. Expect the grading to be difficult—in particular, we reserve scores of 9 only for the most stunningly accurate, insightful, beautifully polished work. However, you may *rewrite* at least three of these (more, at our discretion), for up to a 2-point increase in your score; rewrites needed to be handed in within one week of the return of your work.

The take-home final exam will be worth 21 points.

The collaborative project will be worth 16 points.

We know full well that assignments sometimes come due at awkward times; so to help you manage your work flow, you will have an allotment of *7 late days*

that you can use, throughout the semester (and in any configuration), if for some reason you can't get a given assignment in on time. (You may not use these for the collaborative project.) Once they're used up, you'll only get partial credit for a late assignment. (Nb: A weekend is *two* days long.)

The linear algebra worksheet will not be graded; however, it is a condition on passing this course that you answer every question on it correctly. We do not intend this to be some hellacious struggle, so you should ask for as much help as you need.

If you bomb (or don't show up in time for) one of the REYDR quizzes, it'll cost you a point. Plus, you'll be embarrassed. 'Cuz they *are* ridiculously easy.

Remember that you have to come to class, and section, *on time*. What happens if you don't? Sadly, you will lose points off your final score for the class. If N is the number of unexcused absences/tardies (from class, *or* section), then your points lost will equal N(N-1)/5.

Finally, we will adopt the following grading scale for the course:

95 points or more: guaranteed A.
91 points or more: guaranteed minimum grade of A-.
88 points or more: guaranteed minimum grade of B+.
85 points or more: guaranteed minimum grade of B.
81 points or more: guaranteed minimum grade of B-.
78 points or more: guaranteed minimum grade of C+.
75 points or more: guaranteed minimum grade of C.
71 points or more: guaranteed minimum grade of C-.
65 points or more: guaranteed minimum grade of D.
less than 65 points: no guarantees!

We reserve the right to adjust the grading thresholds *downwards* (that is, to make it *easier* to achieve a certain grade). We won't adjust them upwards.

Web site:

The course web site can always be consulted, if you're unsure what readings have been assigned, what homework is coming due, etc. I'll post a regularly updated schedule, and all materials you need can be found there as well.

SOLACE sections:

We will arrange special *optional* sections early on in the class, explicitly designed to help those of you who need it to get up to speed on the mathematical material we're going to use. More details on scheduling these, in week 2.

Collaboration:

Thanks to the Notorious Cheating Scandal of 2012, I'm supposed to say something about collaboration. Here goes.

Let's start with the obvious. Suppose you have written something in response to a homework assignment, or to the take-home final. Here is what I expect to have happened: As you sat down to write your sentences (or equations, as the case may be), you (i) focused your attention on the question you were addressing; (ii) drew on your *understanding* of the relevant material in order to formulate, in your head, the best answer you could think of; (iii) worked out how to formulate that answer as clearly as possible in English (or math); (iv) moved your fingers across your keyboard in the appropriate way so as to put your formulated answer onto paper (or the electronic equivalent).

Here is an example of what you should *not* be doing, especially at stage (ii): drawing on your mere memory, written notes, etc. of what someone *else* said was a good answer to the question, and transcribing it. If you do that, and we catch you, we will be sad. And so, shortly thereafter, will you.

But look: you *knew* all this, and it's only because of that NCS-2012 that I'm mentioning it at all.

Here is something that you may not have known: Within the boundaries set by the foregoing restrictions, *I would like you all to collaborate as much as possible*. Do not help each other memorize answers; that's stupid. Rather, help each other – as much as you want! – *work out* what a good answer is, and why it's a good answer. If you do *that*, and we catch you at it, we will be happy.

Accommodations for students with disabilities:

Students needing academic adjustments or accommodations because of a documented disability must present their Faculty Letter from the Accessible Education Office (AEO) and speak with the professor by the end of the second week of the term. Failure to do so may result in the Course Head's inability to respond in a timely manner. All discussions will remain confidential.

Summary:

The key course components to keep track of are

- the readings;

- the 7 homework assignments;
- your response/question for each week (due Sunday);
- the collaborative project;
- the final exam;
- the linear algebra worksheet.

Course schedule:

I have pretty much *never*, in my entire academic career, been able to both map out a course schedule ahead of time, and stick to that schedule. *Very roughly*, the arc of the course will look like this:

I. Overview of Some Odd Phenomena (3 weeks)

Maudlin, Chapter 1.

II. The Mathematical Formalism (3 weeks)

Maudlin, Chapter 2; supplemental readings.

III. The Measurement Problem, Attempted Solutions, and their Consequences (5 weeks)

Maudlin, Chapters 3-6; supplemental readings.

IV. Quantum Extravagances (2 weeks)

Supplemental readings: topics may include one or more of quantum logic, quantum faster-than-light signaling, quantum teleportation, quantum computing, quantum cryptography.

What I will do as we go along is to post and update a schedule, which I promise will always be at least reasonably accurate for the near future.