24.111 Philosophy of Quantum Mechanics Spring, 2002

Description: Quantum mechanics—even in the ordinary, non-relativistic, "particle" formulation that will be the primary focus of this course—has been a staggeringly successful physical theory, surely 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 fundamental revision, and much, much more. In this course, we intelligent and sensible people will attempt to 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. Doing so will require learning some math: not the heavy-metal differential equations and approximation techniques that you need to actually start making predictions with the theory, but rather the simple, elegant linear algebra that lies behind the way physical states are represented in quantum mechanics, and that leads in a surprisingly direct fashion to most of the interesting problems that we will discuss. So, after mastering what we need of this mathematical formalism (with no prior exposure to either it or quantum physics required), we will turn to the most famous foundational issues associated with quantum mechanics: the problem of coming up with an adequate account of measurement, the question of whether quantum mechanics can and should be replaced by a "deeper" theory which posits "hidden variables", quantum logic, and (time permitting) some seldom discussed problems associated with the quantum mechanical treatment of composition and identical particles. In addition, we may (again, time permitting) take a skeptical look at recent claims that quantum mechanics will make possible faster-than-light communication, or teleportation, or massive improvement in the computational power of computers.

Along the way, we will take plenty of time out to discuss philosophical questions about science that quantum mechanics raises in new and interesting ways: e.g., what it means to attribute probabilities to physical events, what the aims of scientific inquiry are (does it aim at something *true*, or merely at something *useful*?), what the role of observation is in constructing a scientific theory, what it means to say that there is an "objective" physical world, whether something as basic as logic can be viewed as an empirical discipline, whether there can be meaningful scientific questions whose answers cannot possibly be settled by experiment, and more.

Readings: The required texts for the course is Albert's *Quantum Mechanics and Experience* and Hughes's *The Structure and Interpretation of Quantum Mechanics*. Additional readings (usually articles) will be handed out in class at various points throughout the course. The material is, in most cases, trickier than meets the eye; read it *twice*.

Assignments: You will have weekly homework assignments, which will typically involve 2-3 pages of writing (1 page = 350 words). Don't even think about turning them in late, unless you have some *massively* good excuse that you tell me well ahead of time; we won't accept them. There will be 12 weekly assignments in all; you are required to do 10 (your choice). If you do more, we will pick the ten best in determining your grade. *You are free to revise any assignment*—provided you notify us right away that you want to do so, and turn in the revision no more than two weeks after the given assignment was handed back to you. Occasionally, I may replace the weekly assignment by an in-class quiz; the probability that I will do so will be inversely proportional to my degree of confidence that everyone is doing the reading. There is no final exam, and no mid-term.

Grading: The weekly homework assignments will contribute 70% of your grade, and class participation 30%. 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 7; we will also give you regular feedback on how well you are holding up your end of class discussion. Note that except for the first week, we will typically divide class time into lecture once a week, followed by discussion once a week. For discussion, we will split up into two groups. You will all be expected to give at least one short presentation in your discussion section. Note that attendance at both lecture and discussion is mandatory—and that discussion is still encouraged (though not required) during the lectures!

Course outline: Assuming that my parenthetical estimates are accurate (they probably aren't), we will proceed as follows (with supplemental readings likely, at each stage):

I. Overview of Some Odd Phenomena (2 weeks)

Albert, Chapters 1 & 3; Hughes, Preface and Introduction; supplemental readings.

II. The Mathematical Formalism, and Its Orthodox Interpretation (2 weeks)

Albert, Chapter 2; Hughes, Chapters 1-5; supplemental readings.

III. The Measurement Problem, and Attempted Solutions (4 weeks)

Albert, Chapters 4-7; supplemental readings.

IV. Hidden Variables, and Proofs of Their Impossibility (2 weeks)

Hughes, Chapter 6; supplemental readings.

V. Quantum Extravagances (1.5 weeks)

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

VI. Composition and Identical Particles (1.5 weeks)

Supplemental readings.