Philosophy of QM 24.111

First lecture.

WHAT IS PHILOSOPHY?

One (passable) answer: The discipline that studies — **RIGOROUSLY!**—questions too fundamental to be of interest to anyone else.

Examples: Is there an external world? If so, how is knowledge about it possible? Etc.

Ground rules for philosophical discussion:

1. Be clear.
2. Be explicit.
3. Stay focused.
4. Be sincere!

WHAT IS QUANTUM MECHANICS?

Answer: The physical theory that describes the world on a very small scale.

However:

- Not just the small scale—since large things are *made out of* small things.
- Not just one theory, but a family of related theories—e.g., the quantum theory of particles, fields, strings, etc.

We will focus on the simplest quantum theory: the non-relativistic quantum theory of particles.

WHAT THE EXPERTS SAY:

Richard Feynman, QED:

What I am going to tell you about is what we teach our physics students in the third or fourth year of graduate school—and you think I'm going to explain it to you so you can understand it? No, you're not going to be able to understand it. Why, then, am I going to bother you with all this? Why are you going to sit here all this time, when you won't be able to understand what I am going to say? It is my task to convince you *not* to turn away because you don't understand it. You see, my physics student don't understand it either. That is because *I* don't understand it. Nobody does.

WHAT THE EXPERTS SAY:

Richard Feynman, QED:

George Greenstein & Arthur Zajonc, The Quantum Challen

In our view, modern research has only made the [quantum] theory's paradoxical nature more evident. Our thesis in this book is that the quantum universe forces upon us a radical revision in our conception of the physical world, a revision that has by no means been achieved. Our aim is not to accomplish this task, for we have no idea how this could be done. Rather, our aim is to make as vivid as possible the difficulties of interpretation posed by quantum mechanics.

WHAT THE EXPERTS SAY:

Richard Feynman, QED:

George Greenstein & Arthur Zajonc, The Quantum Challenge:

Roger Penrose, The Emperor's New Mind:

We must indeed come to terms with quantum theory—that most exact and mysterious of physical theories—if we are to delve deeply into some major questions of philosophy: how *does* our world behave, and what constitutes the 'minds' that are, indeed, 'us'?

WHAT THE EXPERTS SAY:

Richard Feynman, QED:

George Greenstein & Arth
Zajonc, The Quantum Cha

Roger Penrose, The
Emperor's New Mind:

David Lindley, T
End of Physics:

The founding principle of classical physics is that a real, objective world exists, a world the scientist can understand in limitless detail. Quantum theory takes away this certainty, asserting that scientists cannot hope to discover the "real" world in infinite detail, not because there is any limit to their intellectual ingenuity or technical expertise, nor even because there are laws of physics preventing the attainment of perfect knowledge. The basis of quantum theory is more revolutionary yet: it asserts that perfect objective knowledge of the world cannot be had because there is no objective world.

WHAT THE EXPERTS SAY:

Richard Feynman, QED:

George Greenstein & Arth
Zajonc, The Quantum Cha

Roger Penrose, The Emperor's New Mind:

David Lindley, The End of Physics:

Steven Weinberg, Dr ams
a Final Theory:

Most physicists use quantum mechanics every day in their working lives without needing to worry about the fundamental problem of its interpretation. Being sensible people with very little time to follow up all the ideas and data in their own specialties and not having to worry about this fundamental problem, they do not worry about it. A year or so ago, while Philip Candelas (of the physics department at Texas) and I were waiting for an elevator, our conversation turned to a young theorist who had been quite promising as a graduate student and who had then dropped out of sight. I asked Phil what had interfered with the ex-student's research. Phil shook his head sadly and said, "He tried to understand quantum mechanics."

TWO AIMS OF SCIENCE:

1. EXPLANATION:

Science should provide us with theories that render intelligible and unsurprising phenomena that would otherwise seem incomprehensibly mysterious.

Example: Fresnel spot.

2. PREDICTION:

Science should provide us with theories that can accurately and precisely predict the phenomena in their domains, in a non-*ad hoc* fashion.

Example: Newtonian celestial mechanics.

CAN WE HAVE EXPLANATION WITHOUT PREDICTION?

Yes—although it's often a sign that something has gone horribly wrong. (Consider, for example, Freudian psychology.)

CAN WE HAVE (HIGH-ACCURACY) PREDICTION WITHOUT EXPLANATION?

One might have thought not—until quantum mechanics came along. (By the way, how good are the predictions of quantum mechanics? *Uncanny.* For example, here is Feynman, from QED:)

CAN WE HAVE EXPLANATION

Just to give you an idea of how the theory has been put through the wringer, I'll give you some recent numbers: experiments have Dirac's number at
1.00115965221
(with an uncertainty of about 4 in the last digit); the theory puts it at
1.00115965246
(with an uncertainty of about five times as much). To give you a feeling for the accuracy of these numbers, it comes out something like this: If you were to measure the distance from Los Angeles to New York to this accuracy, it would be exact to the thickness of a human hair.

mechanics came along. (By th good are the predictions of quantum mechani *Jncanny.* For example, here is Feynman, from QED:)

Fresnel spot: what we see when we shine a light at an opaque disk.