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Instructions: Choose ~~three~~ two of these five questions, and answer them in essay form. There are no upper or lower limits on length – take as much or as little to do justice to the questions – but probably between 500 and 1000 words per question should do the job. (For comparison purposes, this problem set is approximately 1200 words.)

Grading will be based mostly on how well you understand the material and the creativity and cogency of your arguments, but how well your essays are structured and written will also be a consideration. Feel free to take whatever positions you like on the relevant issues, as long as you can defend them effectively. Each question has multiple parts; feel free to tackle them all, or focus on the ones you care most about. [Ten points per essay, 30 points total.]

(Needless to say, answers should be typed, not hand-written.)

1 Probability in Everett

Philosopher Tim Maudlin has put forward a challenge for proponents of the MWI. Imagine a Schrödinger's-Cat-like experiment with two boxes A and B, set up to evolve into two branches: one with amplitude $\sqrt{2/3}$, where poison gas is released into box A, and one with amplitude $\sqrt{1/3}$, where poison gas is released into box B. Held at gunpoint (in the best gruesome tradition of physics thought-experiments), you are forced to put your beloved cat, Erwin, into one of these two boxes. If wave-function collapse were real and truly stochastic, there would be no issue: you would put Erwin in box B, where at least there's a 2/3 chance he would survive. But according to MWI, both branches become real. After the experiment is complete, there will certainly be one branch in which Erwin is alive, and another in which he is dead. The only difference is the amplitude associated with the two branches. Maudlin asks: "Why, as an agent, should you care about this proportional difference in squared-amplitudes?" You are not, he reminds us, really making a choice between the two mutually-exclusive alternatives "Erwin dies" and "Erwin survives," since both alternatives will come true.

In your view, does this kind of challenge represent a difficulty for taking MWI seriously as an understanding of quantum mechanics? Is treating squared-amplitudes "as if" they are stochastic probabilities really sufficient? How would you explain this to Erwin, as you placed him in a box? Should you be just as happy/sad about what happens on other branches of the wave function as you are about what happens on the one you are in?

2 Shut Up and Calculate

Most courses (at least in physics departments) on quantum mechanics never really touch on the foundations of the subject. Physicist David Mermin has suggested (sometimes incorrectly attributed to Richard Feynman or someone else) that the prevailing attitude among physicists is "shut up and calculate." In other words, that we have been doing physics perfectly well for many years now without getting tied up in philosophical dilemmas about the foundations of QM.

Do you think “shut up and calculate” is a defensible attitude for physicists to have toward the foundations of QM, or should they take the measurement problem and other issues more seriously? Does it depend on what kind of physics they are trying to do? Are there physics mistakes we could make by ignoring foundational issues, or on the contrary could we lose focus on more important questions by spending time on foundations? How should these issues be treated in intro/upper-level/graduate courses on QM?

3 Better Physics vs. Better Philosophy

To very roughly generalize, philosophers of physics tend to prefer hidden-variable or dynamical-collapse approaches to QM, which are arguably clunky but at least very clean and well-defined (where they are defined at all). Physicists, meanwhile, tend to gravitate toward MWI or perhaps epistemic approaches like Quantum Bayesianism, where the formalisms are simple but the rules are arguably more vague. Philosopher David Wallace has characterized this tendency as “Faced with the difficulties of quantum mechanics, philosophers are quick to suggest that we need better physics, while physicists are sure the answers lie in better philosophy.”

Where do you tend to come down on this dichotomy? In other words, how comfortable are you with the idea that the measurement problem and other questions at the foundations of QM should be taken as evidence that we need a truly different theory, such as GRW or Bohmian mechanics? If you do tend to be sympathetic with one approach or the other, where do you think your leaning comes from, and do you think it’s defensible?

4 The Limits of Science

Imagine we had finally put together an honest-to-goodness theory of everything – a set of dynamical equations governing both gravity and all of the particles and forces, one that was completely compatible with experiment and made a series of novel experimental predictions that were quickly tested and verified. We have every reason to think this new theory is true. Except that it actually comes in two forms, differing only in their stance toward the foundations of quantum mechanics. One formulation of the theory was an Everettian approach, with branching and decoherence and all the rest. The other formulation was a hidden-variables version, with only one world being “real” and the randomness of quantum measurements attributed to our lack of perfect knowledge about the additional variables. These two versions of the theory (for appropriate choices of the new variables) give exactly the same experimental predictions in every conceivable circumstance.

Given this hypothetical setup, is it sensible to treat these two (empirically indistinguishable) theories as truly different? Is the question of which one of them is “right” a scientific one, or is it purely philosophical (or not even well-posed at all)? Do you think such a situation could actually ever arise, with both theories being equally well-defined? If it did, could we imagine coming to prefer one theory over the other on the basis of pure thought, or would we be stuck in perpetual uncertainty?

5 Cherished Preconceptions

Albert Einstein helped to found quantum mechanics, but came to be dissatisfied with it as a complete description of the world. At different times he objected to it for different reasons: the existence of randomness as opposed to determinism, the lack of locality due to entanglement and the EPR experiment, or a worry that the Copenhagen approach cast reality as something ultimately mysterious and unknowable.

When we do physics, to what extent are cherished preconceptions such as this (e.g. "physics must be deterministic") useful or just a distraction? Can they help guide us to the ultimate truth, or should scientists work to free themselves from any preconceptions about Nature whatsoever? If we do admit the importance of such preconceptions, at what point should we be forced to give them up? E.g., once Bell's Theorem demonstrated the impossibility of local elements of reality in the way Einstein would have preferred, should he have readily abandoned his stance?
