Intermediate Philosophy of Physics: Philosophy of Quantum Mechanics
Somerville College
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1. EPR and nonlocality

Essay question: Outline the Bell nonlocality theorem. What does it tell us about the interpretation of quantum theory?

Core Reading

M. Redhead, *Incompleteness, nonlocality and realism: a prolegomenon to the philosophy of quantum mechanics.* (Clarendon, 1987). Chapter 3 (pp. 71-81).

J. S. Bell "Bertlmann's socks and the nature of reality". *Journal de Physique,* Colloque C2, suppl. au numero 3, Tome 42 (1981), pp. C2 41-61. Reprinted in J.S.Bell, *Speakable and Unspeakable in Quantum Mechanics* (Cambridge, 1987), pp. 139-158.

R. I. G. Hughes, *The Structure and Interpretation of Quantum Mechanics* (Harvard, 1989), sections 6.2, 6.3, 6.7, 8.6.

T. Maudlin, *Quantum non-locality and relativity: metaphysical intimations of modern physics.* (Blackwell, 1994), especially chapters 1 (pp.6-28), 5 (pp.125-161), 7 (pp.189-222).
A detailed account of Bell's theorem (ch.1) and its implications for causality (ch.5) and for Lorentz covariance (ch.7).

Further Reading

J. N. Butterfield, "Bell's Theorem: What it takes", *British Journal for the Philosophy of Science 43* (1992), pp. 41-83. Available online via TDNet.
A careful classification of exactly what the Bell result does and does not show.

2. De Broglie-Bohm pilot wave theory

Essay: How satisfactory is the de Broglie-Bohm theory as a resolution of the measurement problem?
(You may wish to discuss issues with the de Broglie-Bohm theory specifically, and/or the general hidden-variables strategy)

Core Reading

D. Albert, *Quantum Mechanics and Experience* (Harvard University Press, 1992), Chapter 7 (pp. 134-179).

D. Dürr, S. Goldstein, and N. Zanghì, "Bohmian Mechanics and the Meaning of the Wave Function," in Cohen, R. S., Horne, M., and Stachel, J., eds., *Experimental Metaphysics -- Quantum Mechanical Studies for Abner Shimony, Volume One; Boston Studies in the Philosophy of Science* **193**, (Kluwer Academic Publishers, 1997). Available online at http://uk.arxiv.org/abs/quant-ph/9512031

J.S. Bell, "Quantum Mechanics for Cosmologists", in *Quantum Gravity 2,* C. Isham, R. Penrose and D. Sciama (ed.) (Oxford, 1981), pp. 611-637. Reprinted in J.S.Bell, *Speakable and Unspeakable in Quantum Mechanics* (Cambridge, 1987), pp. 117-139. Section 4.

D. Wallace, "Hidden-Variable Theories", section 6 of D.Wallace, "The Philosophy of Quantum Mechanics", in D. Rickles (ed.) *The Ashgate Companion to Philosophy of Physics.* Available online at http://users.ox.ac.uk/~mert0130 under the title "The Measurement Problem: State of Play". Especially sections 6.1, 6.2 and 6.4.

Further Reading

On hidden variables and impossibility proofs in general:

M. Redhead, *Incompleteness, nonlocality and realism: a prolegomenon to the philosophy of quantum mechanics.* (Clarendon, 1987). Chapter 5 (pp. 119-138).
(A careful discussion of the Kochen-Specker paradox and its implications)

On the pilot-wave theory in particular:

J. S. Bell, "On the impossible pilot wave", *Foundations of Physics 12* (1982), pp. 989-99. Reprinted in J.S.Bell, *Speakable and Unspeakable in Quantum Mechanics* (Cambridge, 1987), pp. 201-212.
(Another presentation of the theory).

H Brown *et al*, "Cause and Effect in the Pilot Wave Interpretation of Quantum Mechanics", in J.T. Cushing *et al* (eds.), *Bohmian mechanics and Quantum Theory: An Appraisal* (Kluwer Academic Publishers, 1996).

H. Brown, and D. Wallace, "Solving the measurement problem: de Broglie-Bohm loses out to Everett". *Foundations of Physics 35* (2005), pp.517-540. Available online at http://uk.arxiv.org/abs/quant-ph/0403094

Michael Dickson, 'Antidote or Theory?', *Studies in History and Philosophy of Modern Physics*, **27B**, 229 (1996). Available online via TDNet.
A book review of two recent-ish discussions of the Bohm theory, with much useful background.

G. Ghirardi, "Bohm's Theory versus Dynamical Reduction", in in J.T. Cushing *et al* (eds.), *Bohmian mechanics and Quantum Theory: An Appraisal* (Kluwer Academic Publishers, 1996), pp. 353-377.
Comparison of the pilot-wave theory with dynamical collapse theories of GRW type.

3. Dynamical collapse theories

Essay: Does the Ghirardi-Rimini-Weber theory solve the measurement problem satisfactorily?

Core Reading

G. Ghirardi, "Collapse Theories". *The Stanford Encyclopedia of Philosophy (Spring 2002 Edition)*, Edward N. Zalta (ed.),
http://plato.stanford.edu/archives/spr2002/entries/qm-collapse/.

D.Albert, and B. Loewer, "Tails of Schrodinger's Cat", in *Perspectives on Quantum Reality: non-relativistic, relativistic, field-theoretic*, Rob Clifton (ed.) (Kluwer, 1996). Available online at
http://philosophy.rutgers.edu/FACSTAFF/BIOS/PAPERS/LOEWER/loewer-schroedingers-cat.pdf

P. J. Lewis, "Interpreting Spontaneous Collapse Theories", 2004. Available online from http://philsci-archive.pitt.edu/archive/00001928/

Further Reading

J.S. Bell, "Are there quantum jumps?", in *Schrodinger: Century of a Polymath* (Cambridge, 1987). Reprinted in J.S.Bell, *Speakable and Unspeakable in Quantum Mechanics* (Cambridge, 1987), pp. 201-212. Sections 1-3 and 5.
(An alternative presentation of the GRW collapse theory)

D. Home, *Conceptual Foundations of Quantum Physics: an overview from modern perspectives.* (Plenum, 1997) pp. 97-118.
Rather more technical detail about the GRW theory and its successors, including an overview of Pearle's modification of the GRW program.

T.Maudlin, *Quantum non-locality and relativity: metaphysical intimations of modern physics.* (Blackwell, 1994). Chapter 7 (pp. 189-222).

W. Myrvold, "On peaceful co-existence: is the collapse postulate incompatible with relativity?", *Studies in the History and Philosophy of Modern Physics 33* (2002), pp. 435-66. Available online via TDNet.
(Two viewpoints on the possibility of Lorentz-covariant collapse theories.)

Many further references on the "counting anomaly" may be found in the paper by Lewis, above.

4. The Everett interpretation

Essay: Compare and contrast Everettian interpretations of quantum theory with the de Broglie-Bohm pilot wave approach. Which is preferable as a solution to the measurement problem, and why?

Albert, D. *Quantum Mechanics and Experience* (Harvard University Press, 1992). First part of chapter 6 (pp. 111-119).

Bell, J.S. 'The measurement theory of Everett and de Broglie's pilot wave', Chpt. 11 in his *Speakable and Unspeakable*.

Bell, J.S. 'Quantum Mechanics for Cosmologists', *Speakable and Unspeakable*, Chpt. 15.

Albert, D and B. Loewer (1988). Interpreting the many-worlds interpretation.
Synthese 77, 195-213.
Discusses the prospects for a "many-minds" version of "the" Everett interpretation.

A. Kent, "Against Many-Worlds Interpretations", online at
http://xxx.arxiv.org/abs/gr-qc/9703089. This is a 1997 update of Kent's 1990 paper of the same name in *International Journal of Modern Physics A5* , pp. 1745-1762.
Critical survey of Everett-type interpretations.

D. Wallace, D. "Everett and Structure", *Studies in the History and Philosophy of Modern Physics 34,* pp. 87-105 (2003). Available online via TDNet.
A defence of a many-worlds interpretation against objections like Kent's.

Greaves, H. 'Probability in the Everett Interpretation' *Philosophy Compass* **2**(1): 109-128 (2006)
Survey of the problem of probability in the Everett interpretation, with references to further articles.

Further Reading

Everett, H. '"Relative State" formulation of quantum mechanics' *Rev Mod Phys* **29**: 454-62 (1957) repr. in Wheeler and Zurek.
A precis of Everett's PhD thesis (the original locus of the Everett interpretation).

Wallace, D. 'Worlds in the Everett Interpretation', *Stud. Hist. Phil. Mod. Phys.* 33 (2002) pp.637-661; arXiv:quant-ph/0103092.
'Quantum probability from subjective likelihood: Improving on Deutsch's proof of the probability rule' *Stud Hist Phil Mod Phys* **38**:311–332 (2007).

Lockwood, M. " 'Many Minds' Interpretations of Quantum Mechanics", *BJPS* 47 (1996) pp.158-88; and replies.

Saunders, S. 'Relativism' in R. Clifton (ed.), *Perspectives on Quantum Reality* (Kluwer, 1996), pp. 125-142.

D. Deutsch, “Comment on Lockwood”, *British Journal for the Philosophy of Science 47* (1996), pp. 222-8. Available online via TDNet.

D. Wallace, “Quantum Probability from Subjective Uncertainty: improving on Deutsch’s proof of the probability rule”, unpublished (2003). Online at http://xxx.arxiv.org/abs/quant-ph/0312157 . Section one only.

G. Bacciagaluppi, "The Role of Decoherence in Quantum Mechanics", *The Stanford Encyclopedia of Philosophy (Winter 2003 Edition)*, Edward N. Zalta (ed.), available at http://plato.stanford.edu/archives/win2003/entries/qm-decoherence/.

J. Barrett, *The quantum mechanics of minds and worlds* (Oxford University Press, 1999), especially chapter 3 (and possibly chapter 6). What is essentially a precis of chapter 3, with some added sections which precis other bits of the book, can be found in Barrett, Jeffrey, "Everett's Relative-State Formulation of Quantum Mechanics",
The Stanford Encyclopedia of Philosophy (Spring 2003 Edition), Edward N. Zalta (ed.), http://plato.stanford.edu/archives/spr2003/entries/qm-everett/ .
A clear exegesis of Everett’s original paper and a variety of comments on later versions of the interpretation.

M. Lockwood, “’Many Minds’ Interpretations of Quantum Mechanics”, *British Journal for the Philosophy of Science 47* (1996), pp. 159-88. Available online via TDNet. (See also the many commentaries in the same issue).
Lockwood’s version of the Everett interpretation, emphasising considerations from the philosophy of mind.

D. Papineau, “Many minds are no worse than one”, *British Journal for the Philosophy of Science 47* (1996), pp. 233-41. Available online via TDNet.
An argument that the probability problem is no worse in the Everett interpretation than in single-universe interpretations.