Philosophical Aspects of Quantum Fields (M8)

J. Butterfield and B. Roberts: Non-Examinable (Part III Level)

Quantum field theory has for many decades been the framework for several basic and outstandingly successful physical theories. Nowadays, it is being addressed by philosophy of physics (which has traditionally concentrated on conceptual questions raised by non-relativistic quantum mechanics and relativity). This course will introduce this literature, and prepare for the sequel course in the Lent Term. The content will be moulded by students' interests. But we plan to discuss such topics as: (i) quantization theory, (ii) field and particle aspects, including localization, (iii) discrete symmetries, especially time-reversal and the CPT theorem.

We expect to first review the general mathematical structure of quantum theories, at the level of the books by Hannabuss, Jordan and Prugovecki. This will lead in to ideas about operator algebras, as in the books by Emch, Haag and Ruetsche. Then we will see these ideas applied to quantum field theories and their foundational issues, as in the books by Araki, Clifton and Landsman (which is Open Access), and various papers: e.g. for the CPT theorem: Swanson, N. (2019), 'Deciphering the algebraic CPT theorem', *Studies in History and Philosophy of Modern Physics* **68** 106-125, available at: http://philsci-archive.pitt.edu/16138/ .

Overall, we expect: (i) to mostly use the books by Folland, and by de Faria and de Melo; and (ii) to prepare for the Lent Term course which will consider quantum field theory on curved spacetime.

Pre-requisites

There are no formal prerequisites. But of course, previous familiarity with quantum mechanics will be essential.

Preliminary Reading

This list of reading gives an overview of the course's topics, and is approximately in order of increasing difficulty.

1. S. Weinberg (1997), 'What is Quantum Field Theory, and What Did We Think It Is?'. Available online at: http://arxiv.org/abs/hep-th/9702027; and in T. Cao, (ed.) *The Conceptual Foundations of Quantum Field Theory.* Cambridge University Press, 1999.

2. D. Wallace (2006), 'In defense of naiveté: The conceptual status of Lagrangian quantum field theory', *Synthese*, **151** (1):33-80, 2006. Available online at: http://arxiv.org/pdf/quant-ph/0112148v1

3. D. Wallace (2001), 'Emergence of particles from bosonic quantum field theory'. Available online at: http://arxiv.org/abs/quant-ph/0112149

4. L. Ruetsche, *Interpreting Quantum Theories*: Chapters 4 to 8 for algebraic methods and their interpretation; Chapters 9 to 11 for field and particle aspects. Oxford University Press, 2011.

Literature

To give an idea of the literature, this list includes only books. On this list, our main resource will be the books by Folland, and by de Faria and de Melo. For mathematical background, we will draw on the books by Hannabuss, Jordan and Prugovecki. For foundational issues, we will draw on the books by Araki, Clifton and Landsman (the last being freely downloadable, and an invaluable resource). For operator algebras, we will also use the books by Emch, Haag and Ruetsche. A recent advanced monograph is Rejzner (2016).

1. E. de Faria and W. de Melo. *Mathematical Aspects of Quantum Field Theory*: up to Chapter 6. Cambridge University Press, 2010.

2. G. Folland. *Quantum Field Theory: a tourist guide for mathematicians*: up to Chapter 6. American Mathematical Society, 2008.

3. K. Hannabuss. *An Introduction to Quantum Theory*: up to Chapter 11. Oxford University Press, 1997.

4. T. Jordan. *Linear Operators for Quantum Mechanics*: especially Chapters 3 to 5. John Wiley 1969; Dover 2006.

5. E.Prugovecki. *Quantum Mechanics in Hilbert Space*: especially Parts III, IV. Academic Press 1981; Dover 2006.

6. H. Araki. *Mathematical Theory of Quantum Fields*: up to Chapter 4. Oxford University Press, 1999.

7. R. Clifton. *Quantum Entanglements*, edited by J. Butterfield and H. Halvorson: Chapters 6 to 9. Oxford University Press 2004.

8. N. Landsman. *Foundations of Quantum Theory*. Springer 2017: especially Chapters 5, 6,7,9,10. Open access: downloadable at: https://link.springer.com/book/10.1007/978-3-319-51777-3

9. G. Emch. *Algebraic Methods in Statistical Mechanics and Quantum Field Theory*: especially Chapter 1. John Wiley 1972; Dover 2009.

10. R. Haag. *Local Quantum Physics: fields, particles, algebras*: Chapters I, II, III and V.4: Springer 1992.

11. K. Rejzner. *Perturbative Algebraic Quantum Field Theory: an introduction for mathematicians*: up to Chapter 5. Springer 2016.

Additional support

One or two Part III essays will be offered in conjunction with this course.