Philosophical Aspects of Classical and Quantum Mechanics (M8)

Non-Examinable (Part III Level)

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This course surveys some philosophical aspects of classical and quantum mechanics. Since philosophy of physics is an inter-disciplinary subject (and the course is not examinable!), we will let the content be influenced by the interests of those attending. But we will begin with elements of (a) the modern formulation of Lagrangian and Hamiltonian mechanics in terms of tangent and cotangent bundles, and (b) the quantum measurement problem (including density matrices, mixtures and decoherence). Then we will continue with such topics as: (i) the treatment of time, and time observables, in both classical and quantum mechanics; (ii) the geometric formulation of quantum mechanics as discussed by Kibble, Gibbons, Ashtekar and Schilling; (iii) symmetry and symmetry principles in physics, including time reversal symmetry; and (iv) uncertainty relations, including analogues in classical mechanics.

Pre-requisites

There are no formal prerequisites. Previous familiarity with the frameworks of classical and quantum mechanics will be essential; but the technicalities of each topic will be developed as needed in the lectures.

Preliminary Reading

Among the many good books about the course's topics, one might pick out as especially inspiring:

1. Weyl, H. *Philosophy of Mathematics and Natural Science*. Princeton University Press, 1949, 2009.
2. Bell, J. *Speakable and Unspeakable in Quantum Mechanics*. Cambridge University Press, 1987, 2004.

Literature

For topics (a) and (b), we expect to use parts of the following. The last item is freely downloadable, and an invaluable resource for the whole course.

1. Geroch, R. "Geometrical quantum mechanics", 1974, http://strangebeautiful.com/other-texts/geroch-geom-qm.pdf
2. Marsden, A. and Ratiu, T. *Introduction to Mechanics and Symmetry*, 2nd Edition, Springer 2002, https://www.fis.unam.mx/~max/mecanica/b_Marsden.pdf
3. Butterfield, J. *On Symplectic Reduction in Classical Mechanics*, in J. Earman and J. Butterfield (eds.) *The Handbook of Philosophy of Physics*, 2 volumes, Elsevier; pp. 1 - 131. Available at: physics/0507194 and at http://philsci-archive.pitt.edu/archive/00002373/

4. Isham, C. *Modern Differential Geometry for Physicists*. World Scientific. 1999.

5. Landsman, N. *Between classical and quantum*. In Butterfield, J. and Earman, J. (eds.) *Handbook of the Philosophy of Physics*, 2 volumes, Elsevier. Available at: http://arxiv.org/abs/quant-ph/0506082, and at: http://philsci-archive.pitt.edu/archive/00002328/

6. Landsman, N. *Foundations of Quantum Theory*. Springer 2017: especially Chapters 1-5 and Chapter 11. Open access: downloadable at: https://link.springer.com/book/10.1007/978-3-319-51777-3

For topics (i)-(iv), we expect to use parts of the following.

(i) Time and time observables

1. Hilgevoord, J., *Time in quantum mechanics*, American Journal of Physics **70**, 301-306 (2002).

2. Roberts, B. *A general perspective on time observables*. Studies in History and Philosophy of Physics, **47**,50-54 (2014), http://philsci-archive.pitt.edu/10600/.

3. Roberts, B. *Observables, Disassembled*, Studies in History and Philosophy of Modern Physics, **63**, 150-162 (2018), http://philsci-archive.pitt.edu/1444.

(ii) Geometric quantum mechanics

1. Gibbons, G.W. *Typical states and density matrices*, Journal of Geometry and Physics, **8**(1-4), 147-162 (1992).

2. Ashtekar, A. and Schilling, T.A. *Geometrical formulation of quantum mechanics*. In Alex Harvey, editor, *On Einstein's path: essays in honor of Engelbert Schücking*, pages 23-65. Springer-Verlag New York, Inc., (1999). https://arxiv.org/abs/gr-qc/9706069

3. Brody, D.C. and Hughston, L.P. *Geometric quantum mechanics*, Journal of Geometry and Physics, **38**, 19-53 (2001), https://arxiv.org/abs/quant-ph/9906086

(iii) Symmetry

1. Roberts, B. *Three myths about time reversal in quantum mechanics*, Philosophy of Science, **84**, 1-20 (2017), http://personal.lse.ac.uk/robert49/pdf/Roberts2017a.pdf.

2. Roberts, B. *Three merry roads to T-violation*. Studies in History and Philosophy of Modern Physics, **52**, 8-15 (2015), http://philsci-archive.pitt.edu/9851/.

3. Roberts, B. *The simple failure of Curie's principle*, Philosophy of Science, **80**, 579-592 (2013), http://philsci-archive.pitt.edu/9862/.

(iv) Uncertainty relations

1. Hilgevoord, J. and Uffink J. (2006), *The uncertainty principle*, Stanford Encyclopedia of Philosophy: http://www.seop.leeds.ac.uk/entries/qt-uncertainty/

2. Uffink, J. (1990), *Measures of Uncertainty and the Uncertainty Principle*, Utrecht University PhD. Available at: http://www.projects.science.uu.nl/igg/jos/

Additional support

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