The feats of electricity

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2010 *Mathematics Subject Classification.* 70B15

Key words and phrases. Electricity, Electromechanics

Abstract. This is an introduction to electricity and various electric machines, and to electrical engineering in general. We first discuss the physics of electricity, and the basics of electrical engineering, with as a motivating example, that we discuss in detail, the light bulbs. We then go on a discussion of radio and related topics, again by insisting on both the underlying physics, and the machinery and engineering involved. Then we get into electromechanics, with the various theoretical findings of Faraday, Maxwell and others explained, and with a detailed discussion regarding the electric engines. Finally, we discuss a number of more modern applications of electricity.

Preface

This is an introduction to electricity and various electric machines, and to electrical engineering in general. We first discuss the physics of electricity, and the basics of electrical engineering, with as a motivating example, that we discuss in detail, the light bulbs. We then go on a discussion of radio and related topics, again by insisting on both the underlying physics, and the machinery and engineering involved. Then we get into electromechanics, with the various theoretical findings of Faraday, Maxwell and others explained, and with a detailed discussion regarding the electric engines. Finally, we discuss a number of more modern applications of electricity.

Cergy, April 2025
Teo Banica

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Congratulations for having read this book, and no exercises for this final chapter.

Bibliography

[1] V.I. Arnold, Mathematical methods of classical mechanics, Springer (1974).

[2] V.I. Arnold, Lectures on partial differential equations, Springer (1997).

[3] M.F. Atiyah, The geometry and physics of knots, Cambridge Univ. Press (1990).

[4] T. Banica, Calculus and applications (2024).

[5] T. Banica, Introduction to modern physics (2025).

[6] R.J. Baxter, Exactly solved models in statistical mechanics, Academic Press (1982).

[7] S.M. Carroll, Spacetime and geometry, Cambridge Univ. Press (2004).

[8] D.D. Clayton, Principles of stellar evolution and nucleosynthesis, Univ. of Chicago Press (1968).

[9] A. Connes, Noncommutative geometry, Academic Press (1994).

[10] W.N. Cottingham and D.A. Greenwood, An introduction to the standard model of particle physics, Cambridge Univ. Press (2012).

[11] P.A. Davidson, Introduction to magnetohydrodynamics, Cambridge Univ. Press (2001).

[12] P. Di Francesco, P. Mathieu and D. Sénéchal, Conformal field theory, Springer (1996).

[13] P.A.M. Dirac, Principles of quantum mechanics, Oxford Univ. Press (1930).

[14] S. Dodelson, Modern cosmology, Academic Press (2003).

[15] A. Einstein, Relativity: the special and the general theory, Dover (1916).

[16] L.C. Evans, Partial differential equations, AMS (1998).

[17] L.D. Faddeev and L. A. Takhtajan, Hamiltonian methods in the theory of solitons, Springer (2007).

[18] E. Fermi, Thermodynamics, Dover (1937).

[19] R.P. Feynman, R.B. Leighton and M. Sands, The Feynman lectures on physics I: mainly mechanics, radiation and heat, Caltech (1963).

[20] R.P. Feynman, R.B. Leighton and M. Sands, The Feynman lectures on physics II: mainly electromagnetism and matter, Caltech (1964).

[21] R.P. Feynman, R.B. Leighton and M. Sands, The Feynman lectures on physics III: quantum mechanics, Caltech (1966).

[22] R.P. Feynman and A.R. Hibbs, Quantum mechanics and path integrals, Dover (1965).

[23] A.P. French, Special relativity, Taylor and Francis (1968).

[24] N. Goldenfeld, Lectures on phase transitions and the renormalization group, CRC Press (1992).

[25] H. Goldstein, C. Safko and J. Poole, Classical mechanics, Addison-Wesley (1980).

[26] M.B. Green, J.H. Schwarz and E. Witten, Superstring theory, Cambridge Univ. Press (2012).

[27] D.J. Griffiths, Introduction to electrodynamics, Cambridge Univ. Press (2017).

[28] D.J. Griffiths and D.F. Schroeter, Introduction to quantum mechanics, Cambridge Univ. Press (2018).

[29] D.J. Griffiths, Introduction to elementary particles, Wiley (2020).

[30] K. Huang, Quantum field theory, Wiley (1998).

[31] K. Huang, Quarks, leptons and gauge fields, World Scientific (1982).

[32] C. Itzykson and J.B. Zuber, Quantum field theory, Dover (1980).

[33] L.P. Kadanoff, Statistical physics: statics, dynamics and renormalization, World Scientific (2000).

[34] T. Kibble and F.H. Berkshire, Classical mechanics, Imperial College Press (1966).

[35] M. Kumar, Quantum: Einstein, Bohr, and the great debate about the nature of reality, Norton (2009).

[36] T. Lancaster and K.M. Blundell, Quantum field theory for the gifted amateur, Oxford Univ. Press (2014).

[37] L.D. Landau and E.M. Lifshitz, Mechanics, Pergamon Press (1960).

[38] L.D. Landau and E.M. Lifshitz, The classical theory of fields, Addison-Wesley (1951).

[39] L.D. Landau and E.M. Lifshitz, Quantum mechanics: non-relativistic theory, Pergamon Press (1959).

[40] V.B. Berestetskii, E.M. Lifshitz and L.P. Pitaevskii, Quantum electrodynamics, Butterworth-Heinemann (1982).

[41] R.K. Pathria and and P.D. Beale, Statistical mechanics, Elsevier (1972).

[42] M. Peskin and D.V. Schroeder, An introduction to quantum field theory, CRC Press (1995).

[43] M. Schwartz, Principles of electrodynamics, Dover (1972).

[44] J. Schwinger, L.L. DeRaad Jr., K.A. Milton and W.Y. Tsai, Classical electrodynamics, CRC Press (1998).

[45] J. Schwinger and B.H. Englert, Quantum mechanics: symbolism of atomic measurements, Springer (2001).

[46] J.R. Taylor, Classical mechanics, Univ. Science Books (2003).

[47] J. von Neumann, Mathematical foundations of quantum mechanics, Princeton Univ. Press (1955).

[48] S. Weinberg, Foundations of modern physics, Cambridge Univ. Press (2011).

[49] S. Weinberg, Lectures on quantum mechanics, Cambridge Univ. Press (2012).

[50] S. Weinberg, Lectures on astrophysics, Cambridge Univ. Press (2019).