

# Bibliography

- Aaronson, S. & D. Gottesman, *Physical Review A* **70** (5) (2004). “Improved simulation of stabilizer circuits”. DOI: [10.1103/physreva.70.052328](#) arXiv:[quant-ph/0406196](#)
- Aharonov, Y. & J. Anandan, *Phys. Rev. Lett.* **58** (16), 1593 (1987). “Phase Change During a Cyclic Quantum Evolution”. DOI: [10.1103/PhysRevLett.58.1593](#)
- Alicea, J., Y. Oreg, G. Refael, F. von Oppen, & M. P. A. Fisher, *Nat Phys* **7** (5), 412 (2011). “Non-Abelian statistics and topological quantum information processing in 1D wire networks”. DOI: [10.1038/nphys1915](#)
- Anandan, J., *Physics Letters A* **133** (4-5), 171 (1988). “Non-adiabatic non-abelian geometric phase”. DOI: [10.1016/0375-9601\(88\)91010-9](#)
- Aspect, A., P. Grangier, & G. Roger, *Phys. Rev. Lett.* **47** (7), 460 (1981). “Experimental Tests of Realistic Local Theories via Bell’s Theorem”.
- Barenco, A., C. H. Bennett, R. Cleve, *et al.*, *Physical Review A* **52** (5), 3457 (1995). “Elementary gates for quantum computation”. DOI: [10.1103/physreva.52.3457](#) arXiv:[quant-ph/9503016](#)
- Bell, J. S., *Rev. Mod. Phys.* **38** (3), 447 (1966). “On the Problem of Hidden Variables in Quantum Mechanics”.
- Bennett, C. H., D. P. DiVincenzo, J. A. Smolin, & W. K. Wootters, *Phys. Rev. A* **54** (5), 3824 (1996). “Mixed-state entanglement and quantum error correction”. DOI: [10.1103/PhysRevA.54.3824](#) arXiv:[quant-ph/9604024](#)
- Bennett, C. H. & S. J. Wiesner, *Phys. Rev. Lett.* **69** (20), 2881 (1992). “Communication via one- and two-particle operators on Einstein-Podolsky-Rosen states”.
- Bergou, J. A., U. Herzog, & M. Hillery, “Discrimination of Quantum States,” in [Paris & Rehacek \(2004\)](#), Chap. 11, pp. 417–465. DOI: [10.1007/978-3-540-44481-7\\_11](#)

- Bernstein, E. & U. Vazirani, “Quantum Complexity Theory,” in *Proceedings of the 25th Annual ACM Symposium on the Theory of Computing* (ACM Press, New York, 1993), pp. 11–20.
- Bernstein, E. & U. Vazirani, *SIAM Journal on Computing* **26** (5), 1411 (1997). “Quantum Complexity Theory”. DOI: [10.1137/s0097539796300921](https://doi.org/10.1137/s0097539796300921)
- Berry, M. V., *Proc. R. Soc. London A* **392**, 45 (1984). “Quantal Phase Factors Accompanying Adiabatic Changes”.
- Blum, K., *Density Matrix Theory and Applications*, Vol. 64 of *Springer Series on Atomic, Optical, and Plasma Physics* (Springer Berlin Heidelberg, 2012), 3rd ed., ISBN 978-3-642-20560-6.
- Bohr, N., “Discussion with Albert Einstein on Epistemological Problems in Atomic Physics,” in *Albert Einstein, Philosopher-Scientist*, edited by Schilpp, P. A. (Harper, Evanston, 1949), Vol. VII of *The Library of Living Philosophers*, pp. 200–241, 1st ed.
- Born, M., *Z. Phys.* **37** (12), 863 (1926). “Zur Quantenmechanik der Stoßvorgänge”.
- Bouwmeester, D., J.-W. Pan, M. Daniell, H. Weinfurter, & A. Zeilinger, *Phys. Rev. Lett.* **82** (7), 1345 (1999). “Observation of Three-Photon Greenberger-Horne-Zeilinger Entanglement”.
- Bravyi, S. B. & A. Y. Kitaev, arXiv:[quant-ph/9811052](https://arxiv.org/abs/quant-ph/9811052) (1998). “Quantum codes on a lattice with boundary”.
- Breuer, H.-P. & F. Petruccione, *The Theory of Open Quantum Systems* (Oxford University Press, New York, 2002).
- Browne, D. & H. Briegel, “One-Way Quantum Computation,” in *Quantum Information: From Foundations to Quantum Technology Applications*, edited by Bruß, D. & G. Leuchs (Wiley, 2016), pp. 449–473, 2nd ed. DOI: [10.1002/9783527805785.ch21](https://doi.org/10.1002/9783527805785.ch21) arXiv:[quant-ph/0603226](https://arxiv.org/abs/quant-ph/0603226)
- Calderbank, A. R. & P. W. Shor, *Phys. Rev. A* **54** (2), 1098 (1996). “Good quantum error-correcting codes exist”.
- Caves, C. M., *Phys. Rev. D* **23** (8), 1693 (1981). “Quantum-mechanical noise in an interferometer”.
- Chefles, A., “Quantum States: Discrimination and Classical Information Transmission. A Review of Experimental Progress,” in [Paris & Rehacek \(2004\)](#), Chap. 12, pp. 467–511. DOI: [10.1007/978-3-540-44481-7\\_12](https://doi.org/10.1007/978-3-540-44481-7_12)
- Chiaverini, J., *Science* **308** (5724), 997 (2005). “Implementation of the Semiclassical Quantum Fourier Transform in a Scalable System”. DOI: [10.1126/science.1110335](https://doi.org/10.1126/science.1110335)

- Choi, M.-S., J. Phys.: Condens. Matt. **15** (**46**), 7823 (2003). “Geometric Quantum Computation in Solid-State Qubits”. arXiv:[quant-ph/0111019](#)
- Clauser, J. F., M. A. Horne, A. Shimony, & R. A. Holt, Phys. Rev. Lett. **23**, 880 (1969). “Proposed Experiment to Test Local Hidden-Variable Theories”.
- Cleve, R., A. Ekert, C. Macchiavello, & M. Mosca, Proceedings of the Royal Society A **454** (**1969**), 339 (1998). “Quantum algorithms revisited”. DOI: [10.1098/rspa.1998.0164](#) arXiv:[quant-ph/9708016](#)
- Cleve, R. & D. Gottesman, Physical Review A **56** (**1**), 76 (1997). “Efficient computations of encodings for quantum error correction”. DOI: [10.1103/physreva.56.76](#) arXiv:[quant-ph/9607030](#)
- Cornwell, J. F., *Group Theory in Physics*, Vol. I (Academic Press, Orlando, 1984).
- Cornwell, J. F., *Group Theory in Physics: An Introduction* (Academic Press, San Diego, 1997).
- Crease, R. P., Physics World **15** (**9**), 19 (2002). “The most beautiful experiment”. DOI: [10.1088/2058-7058/15/9/22](#)
- Das, A., Y. Ronen, Y. Most, Y. Oreg, M. Heiblum, & H. Shtrikman, Nat Phys **8** (**12**), 887 (2012). “Zero-bias peaks and splitting in an Al-InAs nanowire topological superconductor as a signature of Majorana fermions”.
- Deng, M. T., C. L. Yu, G. Y. Huang, M. Larsson, P. Caroff, & H. Q. Xu, Nano Letters **12** (**12**), 6414 (2012). “Anomalous Zero-Bias Conductance Peak in a Nb-InSb Nanowire-Nb Hybrid Device”.
- Dennis, E., A. Kitaev, A. Landahl, & J. Preskill, Journal of Mathematical Physics **43** (**9**), 4452 (2002). “Topological quantum memory”. DOI: [10.1063/1.1499754](#) arXiv:[quant-ph/0110143](#)
- Deutsch, D., Proc. R. Soc. London A **400**, 97 (1985). “Quantum theory, the Church-Turing principle and the universal quantum computer”. DOI: [10.1098/rspa.1985.0070](#)
- Deutsch, D. & R. Jozsa, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences **439** (**1907**), 553 (1992). “Rapid Solution of Problems by Quantum Computation”. DOI: [10.1098/rspa.1992.0167](#)
- Dirac, P. A. M., *The Principles of Quantum Mechanics* (Oxford University Press, Oxford, 1958), 4th ed.
- DiVincenzo, D. P., Fortschr. Phys. **48**, 771 (2000). “The Physical Implementation of Quantum Computation”. DOI: [10.1002/1521-3978\(200009\)48:9<771::AID-PROP771>3.0.CO;2-E](#) arXiv:[quant-ph/0002077](#)

- Dum, R., A. S. Parkins, P. Zoller, & C. W. Gardiner, Phys. Rev. A **46** (7), 4382 (1992). “Monte Carlo simulation of master equations in quantum optics for vacuum, thermal, and squeezed reservoirs”.
- Einstein, A., B. Podolsky, & N. Rosen, Phys. Rev. **47**, 777 (1935). “Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?”
- Feynman, R., R. B. Leighton, & M. L. Sands, *The Feynman Lectures on Physics*, Vol. III (Addison-Wesley, Redwood City, 1963), 1st ed.
- Fowler, A. G., M. Mariantoni, J. M. Martinis, & A. N. Cleland, Physical Review A **86** (3), 032324 (2012). “Surface codes: Towards practical large-scale quantum computation”. DOI: [10.1103/physreva.86.032324](https://doi.org/10.1103/physreva.86.032324) arXiv:[1208.0928](https://arxiv.org/abs/1208.0928)
- Freedman, M. H., Foundations of Computational Mathematics **1** (2), 183 (2001). “Quantum Computation and the Localization of Modular Functors”. DOI: [10.1007/s102080010006](https://doi.org/10.1007/s102080010006)
- Giovannetti, V., S. Lloyd, & L. Maccone, Physical Review Letters **96** (1), 010401 (2006). “Quantum Metrology”. DOI: [10.1103/PhysRevLett.96.010401](https://doi.org/10.1103/PhysRevLett.96.010401) arXiv:[quant-ph/0509179](https://arxiv.org/abs/quant-ph/0509179)
- Gisin, N., Helv. Phys. Acta **62**, 363 (1989). “Stochastic quantum dynamics and relativity”. DOI: [10.5169/seals-116034](https://doi.org/10.5169/seals-116034)
- Goldstein, S., Phys. Rev. Lett. **72** (13), 1951 (1994). “Nonlocality without inequalities for almost all entangled states for two particles”.
- Gottesman, D., Physical Review A **54** (3), 1862 (1996). “Class of quantum error-correcting codes saturating the quantum Hamming bound”. DOI: [10.1103/physreva.54.1862](https://doi.org/10.1103/physreva.54.1862) arXiv:[quant-ph/9604038](https://arxiv.org/abs/quant-ph/9604038)
- Gottesman, D., *Stabilizer Codes and Quantum Error Correction*, Ph.D. thesis, California Institute of Technology, Pasadena, California (1997). arXiv:[quant-ph/9705052](https://arxiv.org/abs/quant-ph/9705052)
- Gottesman, D., Phys. Rev. A **57** (1), 127 (1998). “Theory of fault-tolerant quantum computation”. DOI: [10.1103/PhysRevA.57.127](https://doi.org/10.1103/PhysRevA.57.127) arXiv:[quant-ph/9702029](https://arxiv.org/abs/quant-ph/9702029)
- Gottesman, D., “The Heisenberg Representation of Quantum Computers,” in *Group22 : proceedings of XXII International Colloquium on Group Theoretical Methods in Physics : Hobart, July 13-17, 1998*, edited by Corney, S. P., R. Delbourgo, & P. D. Jarvis (International Press, Cambridge, MA, 1999), ISBN 978-1571460547. arXiv:[quant-ph/9807006](https://arxiv.org/abs/quant-ph/9807006)
- Greenberger, D. M., M. A. Horne, A. Shimony, & A. Zeilinger, Ame. J. Phys. **58**, 1131 (1990). “Bell’s theorem without inequalities”. DOI: [10.1119/1.16243](https://doi.org/10.1119/1.16243)

- Greenberger, D. M., M. A. Horne, & A. Zeilinger, “Going beyond Bell’s theorem,” in *Bell’s Theorem, Quantum Theory, and Conceptions of the Universe*, edited by Kafatos, M. (Kluwer Academic, Dordrecht, The Netherlands, 1989). arXiv:[0712.0921](#)
- Griffiths, R. B. & C.-S. Niu, Physical Review Letters **76** (17), 3228 (1996). “Semiclassical Fourier Transform for Quantum Computation”. DOI: [10.1103/physrevlett.76.3228](#) arXiv:[quant-ph/9511007](#)
- Grover, L. K., “A fast quantum mechanical algorithm for database search,” in *Proceedings of the 28th Annual ACM Symposium on the Theory of Computing* (ACM Press, New York, 1996), p. 212. arXiv:[quant-ph/9605043](#)
- Grover, L. K., Phys. Rev. Lett. **79** (2), 325 (1997). “Quantum Mechanics Helps in Searching for a Needle in a Haystack”.
- Hardy, L., Phys. Rev. Lett. **68** (20), 2981 (1992). “Quantum Mechanics, Local Realistic Theories, and Lorentz-Invariant Realistic Theories”.
- Hardy, L., Phys. Rev. Lett. **71**, 1665 (1993). “Nonlocality for two particles without inequalities for almost all entangled states”.
- Higgins, B. L., D. W. Berry, S. D. Bartlett, H. M. Wiseman, & G. J. Pryde, Nature **450** (7168), 393 (2007). “Entanglement-free Heisenberg-limited phase estimation”. DOI: [10.1038/nature06257](#) arXiv:[0709.2996](#)
- Horodecki, M., P. Horodecki, & R. Horodecki, Phys. Lett. A **223** (1), 1 (1996). “Separability of mixed states: necessary and sufficient conditions”. DOI: [10.1016/0375-9601\(95\)00930-2](#)
- Horodecki, R., P. Horodecki, M. Horodecki, & K. Horodecki, Rev. Mod. Phys. **81** (2), 865 (2009). “Quantum entanglement”. DOI: [10.1103/RevModPhys.81.865](#)
- Hughston, L. P., R. Jozsa, & W. K. Wootters, Physics Letters A **183** (1), 14 (1993). “A complete classification of quantum ensembles having a given density matrix”. DOI: [10.1016/0375-9601\(93\)90880-9](#)
- Jiang, M., S. Luo, & S. Fu, Physical Review A **87** (2) (2013). “Channel-state duality”. DOI: [10.1103/physreva.87.022310](#)
- Jönsson, C., Z. Physik **161**, 454 (1961). “Electron Diffraction at Multiple Slits”. DOI: [10.1007/BF01342460](#)
- Kitaev, A. Y., Electronic Colloquium on Computational Complexity **3**, 3 (1996). “Quantum measurements and the Abelian Stabilizer Problem”. arXiv:[quant-ph/9511026](#)

- Kitaev, A. Y., Russian Mathematical Surveys **52** (6), 1191 (1997). “Quantum computations: algorithms and error correction”.
- Kitaev, A. Y., Physics-Uspekhi **44** (10S), 131 (2001). “Unpaired Majorana fermions in quantum wires”. DOI: [10.1070/1063-7869/44/10S/S29](https://doi.org/10.1070/1063-7869/44/10S/S29) arXiv:[cond-mat/0010440](https://arxiv.org/abs/cond-mat/0010440)
- Kitaev, A. Y., Ann. Phys. **303** (1), 2 (2003). “Fault-tolerant quantum computation by anyons”. DOI: [10.1016/S0003-4916\(02\)00018-0](https://doi.org/10.1016/S0003-4916(02)00018-0) arXiv:[quant-ph/9707021](https://arxiv.org/abs/quant-ph/9707021)
- Laflamme, R., C. Miquel, J. P. Paz, & W. H. Zurek, Physical Review Letters **77** (1), 198 (1996). “Perfect Quantum Error Correcting Code”. DOI: [10.1103/physrevlett.77.198](https://doi.org/10.1103/physrevlett.77.198) arXiv:[quant-ph/9602019](https://arxiv.org/abs/quant-ph/9602019)
- Lang, S., *Introduction to Linear Algebra*, Undergraduate Texts in Mathematics (Springer New York, New York, 1986), 2nd ed., ISBN 9781461210702. DOI: [10.1007/978-1-4612-1070-2](https://doi.org/10.1007/978-1-4612-1070-2)
- Lang, S., *Linear Algebra* (Springer, Berlin, 1987), 3rd ed., ISBN 978-1-4757-1949-9. DOI: [10.1007/978-1-4757-1949-9](https://doi.org/10.1007/978-1-4757-1949-9)
- Loss, D. & D. P. DiVincenzo, Phys. Rev. A **57** (1), 120 (1998). “Quantum computation with quantum dots”.
- Lundeen, J. S., B. Sutherland, A. Patel, C. Stewart, & C. Bamber, Nature **474** (7350), 188 (2011). “Direct measurement of the quantum wavefunction”. DOI: [10.1038/nature10120](https://doi.org/10.1038/nature10120)
- Mourik, V., K. Zuo, S. M. Frolov, S. R. Plissard, E. P. A. M. Bakkers, & L. P. Kouwenhoven, Science **336** (6084), 1003 (2012). “Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices”.
- Nadj-Perge, S., I. K. Drozdov, J. Li, *et al.*, Science **346** (6209), 602 (2014). “Observation of Majorana fermions in ferromagnetic atomic chains on a superconductor”. DOI: [10.1126/science.1259327](https://doi.org/10.1126/science.1259327) arXiv:<http://www.sciencemag.org/content/346/6209/602.full.pdf>
- Nakazato, H., Y. Hida, K. Yuasa, B. Militello, A. Napoli, & A. Messina, Physical Review A **74** (6), 062113 (2006). “Solution of the Lindblad equation in the Kraus representation”. DOI: [10.1103/physreva.74.062113](https://doi.org/10.1103/physreva.74.062113) arXiv:[quant-ph/0606193](https://arxiv.org/abs/quant-ph/0606193)
- Nielsen, M. & I. L. Chuang, *Quantum computation and quantum information* (Cambridge University Press, New York, 2011), 10th anniversary ed., ISBN 978-1107002173.
- Ozawa, M., Physics Letters A **268** (3), 158 (2000). “Entanglement measures and the Hilbert–Schmidt distance”. DOI: [10.1016/S0375-9601\(00\)00171-7](https://doi.org/10.1016/S0375-9601(00)00171-7)

- Pan, J.-W., D. Bouwmeester, M. Daniell, H. Weinfurter, & A. Zeilinger, *Nature* **403**, 515 (2000). “Experimental test of quantum nonlocality in three-photon Greenberger-Horne-Zeilinger entanglement”.
- Paris, M. & J. Rehacek, eds., *Quantum State Estimation*, Vol. 649 of *Lecture Notes in Physics* (Springer Berlin Heidelberg, Berlin, 2004), ISBN 9783540444817. DOI: [10.1007/b98673](https://doi.org/10.1007/b98673)
- Peres, A., *Phys. Rev. Lett.* **77** (8), 1413 (1996). “Separability Criterion for Density Matrices”. DOI: [10.1103/PhysRevLett.77.1413](https://doi.org/10.1103/PhysRevLett.77.1413) arXiv:[quant-ph/9604005](https://arxiv.org/abs/quant-ph/9604005)
- Pérez-García, D., M. M. Wolf, D. Petz, & M. B. Ruskai, *Journal of Mathematical Physics* **47** (8), 083506 (2006). “Contractivity of positive and trace-preserving maps under  $L_p$  norms”. DOI: [10.1063/1.2218675](https://doi.org/10.1063/1.2218675) arXiv:[math-ph/0601063](https://arxiv.org/abs/math-ph/0601063)
- Plenio, M. B. & P. L. Knight, *Rev. Mod. Phys.* **70** (1), 101 (1998). “The quantum-jump approach to dissipative dynamics in quantum optics”.
- Plenio, M. B. & S. Virmani, *Quant Inf Comput* **7** (1&2), 1 (2007). “An introduction to entanglement measures”. arXiv:[quant-ph/0504163](https://arxiv.org/abs/quant-ph/0504163)
- Preskill, J., “Lecture Notes on Quantum Information and Computation,” unpublished (1998).
- Raussendorf, R. & H. J. Briegel, *Phys. Rev. Lett.* **86** (22), 5188 (2001). “A One-Way Quantum Computer”.
- Raussendorf, R., D. Browne, & H. Briegel, *Journal of Modern Optics* **49** (8), 1299 (2002). “The one-way quantum computer—a non-network model of quantum computation”. DOI: [10.1080/09500340110107487](https://doi.org/10.1080/09500340110107487) arXiv:[quant-ph/0108118](https://arxiv.org/abs/quant-ph/0108118)
- Raussendorf, R., D. E. Browne, & H. J. Briegel, *Phys. Rev. A* **68** (2), 022312 (2003). “Measurement-based quantum computation on cluster states”. DOI: [10.1103/PhysRevA.68.022312](https://doi.org/10.1103/PhysRevA.68.022312) arXiv:[quant-ph/0301052](https://arxiv.org/abs/quant-ph/0301052)
- Schwinger, J., *Proceedings of the National Academy of Sciences* **45** (10), 1542 (1959). “The Algebra Of Microscopic Measurement”. DOI: [10.1073/pnas.45.10.1542](https://doi.org/10.1073/pnas.45.10.1542)
- Shor, P. W., “Algorithms for Quantum Computation: Discrete Logarithms and Factoring,” in *Proceedings of the 35th Annual Symposium on Foundations of Computer Science* (IEEE Computer Society, Washington, DC, USA, 1994), SFCS '94, pp. 124–134. DOI: [10.1109/SFCS.1994.365700](https://doi.org/10.1109/SFCS.1994.365700)
- Shor, P. W., *SIAM Journal on Computing* **26** (5), 1484 (1997). “Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer”. arXiv:[quant-ph/9508027](https://arxiv.org/abs/quant-ph/9508027)



- Simon, D. R., SIAM Journal on Computing **26** (5), 1474 (1997). “On the Power of Quantum Computation”. DOI: [10.1137/s0097539796298637](https://doi.org/10.1137/s0097539796298637)
- Sjöqvist, E., D. M. Tong, L. Mauritz Andersson, B. Hessmo, M. Johansson, & K. Singh, New Journal of Physics **14** (10), 103035 (2012). “Non-adiabatic holonomic quantum computation”. DOI: [10.1088/1367-2630/14/10/103035](https://doi.org/10.1088/1367-2630/14/10/103035) arXiv:[1107.5127](https://arxiv.org/abs/1107.5127)
- Smolin, J. A. & D. P. DiVincenzo, Phys. Rev. A **53** (4), 2855 (1996). “Five two-bit quantum gates are sufficient to implement the quantum Fredkin gate”. DOI: [10.1103/PhysRevA.53.2855](https://doi.org/10.1103/PhysRevA.53.2855)
- Steane, A. M., Phys. Rev. Lett. **77** (5), 793 (1996). “Error Correcting Codes in Quantum Theory”.
- Størmer, E., *Positive Linear Maps of Operator Algebras* (Springer, Berlin, 2013), ISBN 9783642343698. DOI: [10.1007/978-3-642-34369-8](https://doi.org/10.1007/978-3-642-34369-8)
- Tonomura, A., J. Endo, T. Matsuda, T. Kawasaki, & H. Ezawa, Ame. J. Phys. **57** (2), 117 (1989). “Demonstration of single-electron buildup of an interference pattern”. DOI: [10.1119/1.16104](https://doi.org/10.1119/1.16104)
- Vallone, G. & D. Dequal, Physical Review Letters **116** (4), 040502 (2016). “Strong Measurements Give a Better Direct Measurement of the Quantum Wave Function”. DOI: [10.1103/physrevlett.116.040502](https://doi.org/10.1103/physrevlett.116.040502) arXiv:[1504.06551](https://arxiv.org/abs/1504.06551)
- Vedral, V., A. Barenco, & A. Ekert, Physical Review A **54** (1), 147 (1996). “Quantum networks for elementary arithmetic operations”. DOI: [10.1103/physreva.54.147](https://doi.org/10.1103/physreva.54.147) arXiv:[quant-ph/9511018](https://arxiv.org/abs/quant-ph/9511018)
- Vedral, V., M. B. Plenio, M. A. Rippin, & P. L. Knight, Physical Review Letters **78** (12), 2275 (1997). “Quantifying Entanglement”. DOI: [10.1103/physrevlett.78.2275](https://doi.org/10.1103/physrevlett.78.2275)
- Wang, C., J. Harrington, & J. Preskill, Annals of Physics **303** (1), 31 (2003). “Confinement-Higgs transition in a disordered gauge theory and the accuracy threshold for quantum memory”. DOI: [10.1016/s0003-4916\(02\)00019-2](https://doi.org/10.1016/s0003-4916(02)00019-2)
- Wehrl, A., Reviews of Modern Physics **50** (2), 221 (1978). “General properties of entropy”. DOI: [10.1103/revmodphys.50.221](https://doi.org/10.1103/revmodphys.50.221)
- Weyl, H., *The theory of groups and quantum mechanics* (Dover, London, 1931).
- Wigner, E. P., *Group Theory and its Application to the Quantum Mechanics of Atomic Spectra* (Academic Press, New York, 1959), english translation ed.
- Wilczek, F. & A. Zee, Phys. Rev. Lett. **52** (24), 2111 (1984). “Appearance of Gauge Structure in Simple Dynamical Systems”. DOI: [10.1103/PhysRevLett.52.2111](https://doi.org/10.1103/PhysRevLett.52.2111)



- Wilmut, I., A. E. Schnieke, J. McWhir, A. J. Kind, & K. H. S. Campbell, *Nature* **385** (**6619**), 810 (1997). “Viable offspring derived from fetal and adult mammalian cells”.
- Wooters, W. K. & W. H. Zurek, *Nature* **299**, 802 (1982). “A single quantum cannot be cloned”.
- Zanardi, P. & M. Rasetti, *Phys. Lett. A* **264** (**2-3**), 94 (1999). “Holonomic quantum computation”. DOI: [10.1016/S0375-9601\(99\)00803-8](https://doi.org/10.1016/S0375-9601(99)00803-8) arXiv:[quant-ph/9904011](https://arxiv.org/abs/quant-ph/9904011)
- Zurek, W. H., *Phys. Today* **44** (**10**), 36 (1991). “Decoherence and the transition from quantum to classical”.
- Zurek, W. H., *Nature* **404**, 130 (2000). “Quantum cloning: Schrodinger’s sheep”. DOI: [10.1038/35004684](https://doi.org/10.1038/35004684)
- Zurek, W. H., *Los Alamos Science* **27**, 2 (2002). “Decoherence and the Transition from Quantum to Classical: Revisited”.

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