References

[1] Amann, H., and Escher, J. 2008. *Analysis II*. Basel: Birkhäuser Verlag.

[2] Arminjon, M., and Reifler, F. 2010. Basic quantum mechanics for three Dirac equations in a curved spacetime. *Braz. J. Phys.*, **40**(6), 242–255. *arXiv:0807.0570 [gr-qc]*.

[3] Arminjon, M., and Reifler, F. 2011. A non-uniqueness problem of the Dirac theory in a curved spacetime. *Ann. Phys.*, **523**(7), 1521–3889. *arXiv:0905.3686 [gr-qc]*.

[4] Bär, C., and Fredenhagen, K. (eds.) 2009. *Quantum Field Theory on Curved Spacetimes*. Lecture Notes in Physics, vol. 786. Berlin: Springer Verlag.

[5] Bär, C., Gauduchon, P., and Moroianu, A. 2005. Generalized cylinders in semi-Riemannian and spin geometry. *Math. Z.*, **249**(3), 545–580. *arXiv:math/0303095 [math.DG]*.

[6] Bär, C., Ginoux, N., and Pfäffle, F. 2007. *Wave Equations on Lorentzian Manifolds and Quantization*. ESI Lectures in Mathematics and Physics. Zürich: European Mathematical Society (EMS). *arXiv:0806.1036 [math.DG]*.

[7] Barut, A. O. 1980. *Electrodynamics and Classical Theory of Fields & Particles*. Corrected reprint of the 1964 original. New York: Dover Publications, Inc.

[8] Bauer, H. 2001. *Measure and Integration Theory*. De Gruyter Studies in Mathematics, vol. 26. Translated from the German by Robert B. Burckel. Berlin: Walter de Gruyter & Co.

[9] Baum, H. 1985. Spinor structures and Dirac operators on pseudo-Riemannian manifolds. *Bull. Polish Acad. Sci. Math.*, **33**(3–4), 165–171.

[10] Bäuml, L., Finster, F., von der Mosel, H., and Schiefeneder, D. 2019. Singular support of minimizers of the causal variational principle on the sphere. *Calc. Var. Partial Differ. Equ.*, **58**(6), 205. *arXiv:1808.09754 [math.CA]*.

[11] Beem, J. K., Ehrlich, P. E., and Easley, K. L. 1996. *Global Lorentzian Geometry*. 2nd ed. Monographs and Textbooks in Pure and Applied Mathematics, vol. 202. New York: Marcel Dekker, Inc.

[12] Bernal, A. N., and Sánchez, M. 2003. On smooth Cauchy hypersurfaces and Geroch's splitting theorem. *Commun. Math. Phys.*, **243**(3), 461–470. *arXiv:gr-qc/0306108*.

[13] Bernard, Y., and Finster, F. 2014. On the structure of minimizers of causal variational principles in the non-compact and equivariant settings. *Adv. Calc. Var.*, **7**(1), 27–57. *arXiv:1205.0403 [math-ph]*.

[14] Bjorken, J. D., and Drell, S. D. 1964. *Relativistic Quantum Mechanics*. New York: McGraw-Hill Book Co.

[15] Bogachev, V. I. 2007. *Measure Theory, vol. I*. Berlin: Springer-Verlag.

[16] Bognár, J. 1974. *Indefinite Inner Product Spaces*. Ergebnisse der Mathematik und ihrer Grenzgebiete, Band 78. New York: Springer-Verlag.

[17] Bombelli, L., Lee, J., Meyer, D., and Sorkin, R. D. 1987. Space-time as a causal set. *Phys. Rev. Lett.*, **59**(5), 521–524.

[18] Bröcker, T. 1992. *Analysis II*. Mannheim: Bibliographisches Institut.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 12 Nov 2026 at 10:19:45, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009632638

[19] Brunetti, R., Dappiaggi, C., Fredenhagen, K., and Yngvason, J. (eds.) 2015. *Advances in Algebraic Quantum Field Theory*. Mathematical Physics Studies. Berlin: Springer-Verlag.
[20] Chandrasekhar, S. 1998. *The Mathematical Theory of Black Holes*. Oxford Classic Texts in the Physical Sciences. New York: Oxford University Press.
[21] Curiel, E., Finster, F., and Isidro, J. M. 2020. Two-dimensional area and matter flux in the theory of causal fermion systems. *Int. J. Mod. Phys. D*, **29**, 2050098. *arXiv:1910.06161 [math-ph]*.
[22] Dappiaggi, C., and Finster, F. 2020. Linearized fields for causal variational principles: Existence theory and causal structure. *Methods Appl. Anal.*, **27**(1), 1–56. *arXiv:1811.10587 [math-ph]*.
[23] Dappiaggi, C., Finster, F., and Oppio, M. 2022. Linear bosonic quantum field theories arising from causal variational principles. *Lett. Math. Phys.*, **112**, 38. *arXiv:2112.10656 [math-ph]*.
[24] Dappiaggi, C., Finster, F., Kamran, N., and Reintjes, M. 2025. Holographic mixing and Fock space dynamics of causal fermion systems. *Ann. Henri Poincaré*, *arXiv:2410.18045 [math-ph]*.
[25] Deckert, D.-A., and Merkl, F. 2014. Dirac equation with external potential and initial data on Cauchy Surfaces. *J. Math. Phys.*, **55**(12), 122305. *arXiv:1404.1401 [math-ph]*.
[26] Dieudonné, J. 1969. *Foundations of Modern Analysis*. Enlarged and corrected printing, Pure and Applied Mathematics, vol. 10-I. New York-London: Academic Press.
[27] Dimock, J. 1982. Dirac quantum fields on a manifold. *Trans. Am. Math. Soc.*, **269**(1), 133–147.
[28] Dirac, P. A. M. 1930. A theory of electrons and protons. *Proc. R. Soc. Lond. A*, **126**, 360–365.
[29] do Carmo, M. P. 1976. *Differential Geometry of Curves and Surfaces*. Englewood Cliffs, NJ: Prentice-Hall, Inc.
[30] Doković, D. Z., and Thang, N. Q. 1994. Conjugacy classes of maximal tori in simple real algebraic groups and applications. *Canad. J. Math.*, **46**(4), 699–717. Correction: *Canad. J. Math.*, **46** (1994), no. 6, 1208–1210.
[31] Elstrodt, J. 2005. *Maß- und Integrationstheorie*. 4th ed. Grundwissen Mathematik. Berlin: Springer-Verlag.
[32] Evans, L. C. 2010. *Partial Differential Equations*. 2nd ed. Graduate Studies in Mathematics, vol. 19. Providence, RI: American Mathematical Society.
[33] Evans, L. C., and Gariepy, R. F. 1992. *Measure Theory and Fine Properties of Functions*. Studies in Advanced Mathematics. Boca Raton, FL: CRC Press.
[34] Fefferman, C. L. 2005. A sharp form of Whitney's extension theorem. *Ann. Math. (2)*, **161**(1), 509–577.
[35] Finster, F. 1996. Derivation of field equations from the principle of the fermionic projector. *(unpublished preprint in German)*. *arXiv:gr-qc/9606040*.
[36] Finster, F. 1997. Light-cone expansion of the Dirac sea with light cone integrals. *unpublished preprint*. *arXiv:funct-an/9707003*.
[37] Finster, F. 1998. Definition of the Dirac sea in the presence of external fields. *Adv. Theor. Math. Phys.*, **2**(5), 963–985. *arXiv:hep-th/9705006*.
[38] Finster, F. 1998. Local $\mathrm{U}(2,2)$ symmetry in relativistic quantum mechanics. *J. Math. Phys.*, **39**(12), 6276–6290. *arXiv:hep-th/9703083*.
[39] Finster, F. 1999. Light-cone expansion of the Dirac sea to first order in the external potential. *Michigan Math. J.*, **46**(2), 377–408. *arXiv:hep-th/9707128*.
[40] Finster, F. 2000. Light-cone expansion of the Dirac sea in the presence of chiral and scalar potentials. *J. Math. Phys.*, **41**(10), 6689–6746. *arXiv:hep-th/9809019*.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 12 Nov 2026 at 10:19:45, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009632638

[41] Finster, F. 2006. *The Principle of the Fermionic Projector*. AMS/IP Studies in Advanced Mathematics, vol. 35. Providence, RI: American Mathematical Society. *hep-th/0001048, hep-th/0202059, hep-th/0210121.*
[42] Finster, F. 2007. A variational principle in discrete space-time: Existence of minimizers. *Calc. Var. Partial. Differ. Equ.*, **29**(4), 431–453. *arXiv:math-ph/0503069.*
[43] Finster, F. 2010. Causal variational principles on measure spaces. *J. Reine Angew. Math.*, **646**, 141–194. *arXiv:0811.2666 [math-ph].*
[44] Finster, F. 2014. Perturbative quantum field theory in the framework of the fermionic projector. *J. Math. Phys.*, **55**(4), 042301. *arXiv:1310.4121 [math-ph].*
[45] Finster, F. 2016. *The Continuum Limit of Causal Fermion Systems*. Fundamental Theories of Physics, vol. 186. Cham: Springer. *arXiv:1605.04742 [math-ph].*
[46] Finster, F. 2017. The chiral index of the fermionic signature operator. *Math. Res. Lett.*, **24**(1), 37–66. *arXiv:1404.6625 [math-ph].*
[47] Finster, F. 2018. Causal fermion systems: A primer for Lorentzian geometers. *J. Phys.: Conf. Ser.*, **968**, 012004. *arXiv:1709.04781 [math-ph].*
[48] Finster, F. 2019. Causal fermion systems: Discrete space-times, causation and finite propagation speed. *J. Phys.: Conf. Ser.*, **1275**, 012009. *arXiv:1812.00238 [math-ph].*
[49] Finster, F. 2019. Positive functionals induced by minimizers of causal variational principles. *Vietnam J. Math.*, **47**, 23–37. *arXiv:1708.07817 [math-ph].*
[50] Finster, F. 2020. The causal action in Minkowski space and surface layer integrals. *SIGMA Symmetry Integrability Geom. Methods Appl.*, **16**(091), 83. *arXiv:1711.07058 [math-ph].*
[51] Finster, F. 2020. Perturbation theory for critical points of causal variational principles. *Adv. Theor. Math. Phys.*, **24**(3), 563–619. *arXiv:1703.05059 [math-ph].*
[52] Finster, F. 2023. Solving the linearized field equations of the causal action principle in Minkowski space. *Adv. Theor. Math. Phys.*, **27**(7), 2087–2217. *arXiv:2304.00965 [math-ph].*
[53] Finster, F., and Fischer, P. 2025. A canonical construction of the extended Hilbert space for causal fermion systems. *arXiv:2504.18276 [math-ph (2025)].*
[54] Finster, F., and Grotz, A. 2010. The causal perturbation expansion revisited: Rescaling the interacting Dirac sea. *J. Math. Phys.*, **51**(7), 072301. *arXiv:0901.0334 [math-ph].*
[55] Finster, F., and Grotz, A. 2012. A Lorentzian quantum geometry. *Adv. Theor. Math. Phys.*, **16**(4), 1197–1290. *arXiv:1107.2026 [math-ph].*
[56] Finster, F., and Kamran, N. 2019. Spinors on singular spaces and the topology of causal fermion systems. *Mem. Amer. Math. Soc.*, **259**(1251), v+83. *arXiv:1403.7885 [math-ph].*
[57] Finster, F., and Kamran, N. 2021. Complex structures on jet spaces and bosonic Fock space dynamics for causal variational principles. *Pure Appl. Math. Q.*, **17**(1), 55–140. *arXiv:1808.03177 [math-ph].*
[58] Finster, F., and Kamran, N. 2022. Fermionic Fock spaces and quantum states for causal fermion systems. *Ann. Henri Poincaré*, **23**(4), 1359–1398. *arXiv:2101.10793 [math-ph].*
[59] Finster, F., and Kamran, N. 2023. A positive quasilocal mass for causal variational principles. *Calc. Var.*, **64**(3), 91. *arXiv:2310.07544 [math-ph].*
[60] Finster, F., and Kindermann, S. 2020. A gauge fixing procedure for causal fermion systems. *J. Math. Phys.*, **61**(8), 082301. *arXiv:1908.08445 [math-ph].*
[61] Finster, F., and Kleiner, J. 2016. Noether-like theorems for causal variational principles. *Calc. Var. Partial Differ. Equ.*, **55:35**(2), 41. *arXiv:1506.09076 [math-ph].*
[62] Finster, F., and Kleiner, J. 2017. A Hamiltonian formulation of causal variational principles. *Calc. Var. Partial Differ. Equ.*, **56:73**(3), 33. *arXiv:1612.07192 [math-ph].*

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 12 Nov 2026 at 10:19:45, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009632638

[63] Finster, F., and Kleiner, J. 2019. A class of conserved surface layer integrals for causal variational principles. *Calc. Var. Partial Differ. Equ.*, **58:38**(1), 34. *arXiv:1801.08715 [math-ph].*

[64] Finster, F., and Kraus, M. 2020. The regularized Hadamard expansion. *J. Math. Anal. Appl.*, **491**(2), 124340. *arXiv:1708.04447 [math-ph].*

[65] Finster, F., and Kraus, M. 2023. Construction of global solutions to the linearized field equations for causal variational principles. *Methods Appl. Anal.*, **30**(2), 77–94. *arXiv:2210.16665 [math-ph].*

[66] Finster, F., and Langer, C. 2022. Causal variational principles in the σ-locally compact setting: Existence of minimizers. *Adv. Calc. Var.*, **15**(3), 551–575. *arXiv:2002.04412 [math-ph].*

[67] Finster, F., and Lottner, M. 2021. Banach manifold structure and infinite-dimensional analysis for causal fermion systems. *Ann. Global Anal. Geom.*, **60**(2), 313–354. *arXiv:2101.11908 [math-ph].*

[68] Finster, F., and Lottner, M. 2022. Elliptic methods for solving the linearized field equations of causal variational principles. *Calc. Var. Partial Differ. Equ.*, **61**(4), 133. *arXiv:2111.08261 [math-ph].*

[69] Finster, F., and Müller, O. 2016. Lorentzian spectral geometry for globally hyperbolic surfaces. *Adv. Theor. Math. Phys.*, **20**(4), 751–820. *arXiv:1411.3578 [math-ph].*

[70] Finster, F., and Reintjes, M. 2015. A non-perturbative construction of the fermionic projector on globally hyperbolic manifolds I – Space-times of finite lifetime. *Adv. Theor. Math. Phys.*, **19**(4), 761–803. *arXiv:1301.5420 [math-ph].*

[71] Finster, F., and Reintjes, M. 2016. A non-perturbative construction of the fermionic projector on globally hyperbolic manifolds II – Space-times of infinite lifetime. *Adv. Theor. Math. Phys.*, **20**(5), 1007–1048. *arXiv:1312.7209 [math-ph].*

[72] Finster, F., and Röken, C. 2016. Self-adjointness of the Dirac Hamiltonian for a class of non-uniformly elliptic boundary value problems. *Ann. Math. Sci. Appl.*, **1**(2), 301–320. *arXiv:1512.00761 [math-ph].*

[73] Finster, F., and Röken, C. 2019. The fermionic signature operator in the exterior Schwarzschild geometry. *Ann. Henri Poincaré*, **20**(10), 3389–3418. *arXiv:1812.02010 [math-ph].*

[74] Finster, F., and Schiefeneder, D. 2013. On the support of minimizers of causal variational principles. *Arch. Ration. Mech. Anal.*, **210**(2), 321–364. *arXiv:1012.1589 [math-ph].*

[75] Finster, F., and Tolksdorf, J. 2014. Perturbative description of the fermionic projector: Normalization, causality and Furry's theorem. *J. Math. Phys.*, **55**(5), 052301. *arXiv:1401.4353 [math-ph].*

[76] Finster, F., Smoller, J., and Yau, S.-T. 2000. Non-existence of time-periodic solutions of the Dirac equation in a Reissner-Nordström black hole background. *J. Math. Phys.*, **41**(4), 2173–2194. *arXiv:gr-qc/9805050.*

[77] Finster, F., Kamran, N., Smoller, J., and Yau, S.-T. 2000. Nonexistence of time-periodic solutions of the Dirac equation in an axisymmetric black hole geometry. *Comm. Pure Appl. Math.*, **53**(7), 902–929. *arXiv:gr-qc/9905047.*

[78] Finster, F., Kamran, N., Smoller, J., and Yau, S.-T. 2002. Decay rates and probability estimates for massive Dirac particles in the Kerr-Newman black hole geometry. *Commun. Math. Phys.*, **230**(2), 201–244. *arXiv:gr-qc/0107094.*

[79] Finster, F., Kamran, N., Smoller, J., and Yau, S.-T. 2003. The long-time dynamics of Dirac particles in the Kerr-Newman black hole geometry. *Adv. Theor. Math. Phys.*, **7**(1), 25–52. *arXiv:gr-qc/0005088.*

[80] Finster, F., Grotz, A., and Schiefeneder, D. 2012. Causal fermion systems: A quantum space-time emerging from an action principle. Pages 157–182 of: Finster, F., Müller, O., Nardmann, M., Tolksdorf, J., and Zeidler, E. (eds), *Quantum Field Theory and Gravity.* Basel: Birkhäuser Verlag. *arXiv:1102.2585 [math-ph].*

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 12 Nov 2026 at 10:19:45, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009632638

[81] Finster, F., Murro, S., and Röken, C. 2016. The fermionic projector in a time-dependent external potential: Mass oscillation property and Hadamard states. *J. Math. Phys.*, **57**(7), 072303. *arXiv:1501.05522 [math-ph].*

[82] Finster, F., Kamran, N., and Oppio, M. 2021. The linear dynamics of wave functions in causal fermion systems. *J Differ. Equ.*, **293**, 115–187. *arXiv:2101.08673 [math-ph].*

[83] Finster, F., Jonsson, R. H., and Kilbertus, N. 2025. Numerical analysis of the causal action principle in low dimensions. *Comm. Math. Sci. arXiv:2201.06382 [math-ph].*

[84] Finster, F., Kamran, N., and Reintjes, M. 2023. Entangled quantum states of causal fermion systems and unitary group integrals. *Adv. Theor. Math. Phys.*, **27**(5), 1463–1589. *arXiv:2207.13157 [math-ph].*

[85] Finster, F., Frankl, M., and Langer, C. 2024. The homogeneous causal action principle on a compact domain in momentum space. *Adv. Calc. Var.*, **17**(3), 559–585. *arXiv:2205.04085 [math-ph].*

[86] Finster, F., Guendelman, E., and Paganini, C. 2024. Modified measures as an effective theory for causal fermion systems. *Class. Quant. Gravity*, **41**(3), 035007, 25. *arXiv:2303.16566 [gr-qc].*

[87] Folland, G. B. 1999. *Real Analysis: Modern Techniques and Their Applications*. 2nd edn. Pure and Applied Mathematics (New York). New York: John Wiley & Sons, Inc.

[88] Friedlander, F. G. 1975. *The Wave Equation on a Curved Space-Time*. Cambridge: Cambridge University Press.

[89] Friedlander, F. G. 1998. *Introduction to the Theory of Distributions*. 2nd edn. Cambridge: Cambridge University Press, With additional material by M. Joshi.

[90] Friedrich, T. 2000. *Dirac Operators in Riemannian Geometry*. Graduate Studies in Mathematics, vol. 25. Providence, RI: American Mathematical Society.

[91] Friedrichs, K. O. 1954. Symmetric hyperbolic linear differential equations. *Comm. Pure Appl. Math.*, **7**, 345–392.

[92] Friedrichs, K. O. 1958. Symmetric positive linear differential equations. *Comm. Pure Appl. Math.*, **11**, 333–418.

[93] Glimm, J., and Jaffe, A. 1987. *Quantum Physics: A Functional Integral Point of View*. 2nd edn. New York: Springer-Verlag.

[94] Gohberg, I., Lancaster, P., and Rodman, L. 2005. *Indefinite Linear Algebra and Applications*. Basel: Birkhäuser Verlag.

[95] Goldstein, H. 1980. *Classical Mechanics*. 2nd edn. Reading, MA: Addison-Wesley Publishing Co.

[96] Gradshteyn, I. S., and Ryzhik, I. M. 1965. *Table of Integrals, Series, and Products*. Fourth edition prepared by Ju. V. Geronimus and M. Ju. Tseytlin. New York: Academic Press.

[97] Greene, R. E., and Shiohama, K. 1979. Diffeomorphisms and volume-preserving embeddings of noncompact manifolds. *Trans. Amer. Math. Soc.*, **255**, 403–414.

[98] Hack, T.-P. 2010. On the Backreaction of Scalar and Spinor Quantum Fields in Curved Spacetimes – From the Basic Foundations to Cosmological Applications. *Dissertation Universität Hamburg*, viii+254. *arXiv:1008.1776 [gr-qc].*

[99] Hadamard, J. 1953. *Lectures on Cauchy's Problem in Linear Partial Differential Equations*. New York: Dover Publications.

[100] Halmos, P. R. 1958. *Finite-Dimensional Vector Spaces*. The University Series in Undergraduate Mathematics. 2nd ed. Princeton-Toronto-New York-London: D. Van Nostrand Co., Inc.

[101] Halmos, P. R. 1974. *Measure Theory*. New York: Springer.

[102] Hawking, S. W., and Ellis, G. F. R. 1973. *The Large Scale Structure of Space-Time*. London: Cambridge University Press.

[103] Hawking, S. W., King, A. R., and McCarthy, P. J. 1976. A new topology for curved space-time which incorporates the causal, differential, and conformal structures. *J. Math. Phys.*, **17**(2), 174–181.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 12 Nov 2026 at 10:19:45, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009632638

[104] Helgason, S. 2000. *Groups and Geometric Analysis*. Mathematical Surveys and Monographs, vol. 83. Providence, RI: American Mathematical Society. Integral geometry, invariant differential operators, and spherical functions, Corrected reprint of the 1984 original.
[105] Hörmander, L. 1990. *The Analysis of Linear Partial Differential Operators. I*. 2nd edn. Grundlehren der Mathematischen Wissenschaften, vol. 256. Berlin: Springer-Verlag.
[106] Jänich, K. 1984. *Topology*. Undergraduate Texts in Mathematics. New York: Springer-Verlag, With a chapter by Theodor Bröcker, Translated from the German by Silvio Levy.
[107] John, F. 1991. *Partial Differential Equations*. 4th edn. Applied Mathematical Sciences, vol. 1. New York: Springer-Verlag.
[108] Kato, T. 1995. *Perturbation Theory for Linear Operators*. Classics in Mathematics. Berlin: Springer-Verlag.
[109] Kilbertus, N. 2015. Numerical analysis of causal fermion systems on $\mathbb{R} \times S^3$. *Masterarbeit Mathematik, Universität Regensburg*.
[110] Kleinert, H. 2006. *Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets*. 4th edn. Hackensack, NJ: World Scientific Publishing Co. Pte. Ltd.
[111] Landau, L. D., and Lifshitz, E. M. 1958. *Quantum Mechanics: Non-Relativistic Theory*. Course of Theoretical Physics, vol. 3. Translated from the Russian by J. B. Sykes and J. S. Bell, Addison-Wesley Series in Advanced Physics. London-Paris: Pergamon Press Ltd.
[112] Landau, L. D., and Lifshitz, E. M. 1962. *The Classical Theory of Fields*. Revised 2nd edition. Course of Theoretical Physics, vol. 2. Translated from the Russian by M. Hamermesh. Oxford: Pergamon Press.
[113] Lang, S. 1999. *Fundamentals of Differential Geometry*. Graduate Texts in Mathematics, vol. 191. New York: Springer-Verlag.
[114] Finster, F. and Gmeineder, F. 2025. Action-driven flows for causal variational principles. *arXiv:2503.00526 [math-ph]*.
[115] Lawson, Jr., H. B., and Michelsohn, M.-L. 1989. *Spin Geometry*. Princeton Mathematical Series, vol. 38. Princeton, NJ: Princeton University Press.
[116] Lax, P. D. 2002. *Functional Analysis*. Pure and Applied Mathematics (New York). New York: Wiley-Interscience [John Wiley & Sons].
[117] Lee, J. M. 2009. *Manifolds and Differential Geometry*. Graduate Studies in Mathematics, vol. 107. Providence, RI: American Mathematical Society.
[118] Lee, J. M. 2013. *Introduction to Smooth Manifolds*. 2nd edn. Graduate Texts in Mathematics, vol. 218. New York: Springer.
[119] Malament, D. B. 1977. The class of continuous timelike curves determines the topology of spacetime. *J. Math. Phys.*, **18**(7), 1399–1404.
[120] Milnor, J. W., and Stasheff, J. D. 1974. *Characteristic Classes*. Princeton, NJ: Princeton University Press. Annals of Mathematics Studies, No. 76.
[121] Naber, G. L. 2012. *The Geometry of Minkowski Spacetime*. Applied Mathematical Sciences, vol. 92. New York: Springer, An introduction to the mathematics of the special theory of relativity, 2nd edition [of MR1174969].
[122] Noether, E. 1918. Invariante Variationsprobleme. *Nachr. d. König. Gesellsch. d. Wiss. Math-phys. Klasse, Berlin*, **1918**, 235–257.
[123] Nomizu, K., and Ozeki, H. 1961. The existence of complete Riemannian metrics. *Proc. Amer. Math. Soc.*, **12**, 889–891.
[124] Olver, F. W. J., Lozier, D. W., Boisvert, R. F., and Clark, C. W. (eds). 2010. *Digital Library of Mathematical Functions*. Washington, DC: National Institute of Standards and Technology from http://dlmf.nist.gov/ (release date December 15, 2019).

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 12 Nov 2026 at 10:19:45, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009632638

[125] O'Neill, B. 1983. *Semi-Riemannian Geometry*. Pure and Applied Mathematics, vol. 103. New York: Academic Press, Inc. [Harcourt Brace Jovanovich, Publishers].
[126] Palais, R. S. 1979. The principle of symmetric criticality. *Commun. Math. Phys.*, **69**(1), 19–30.
[127] Penrose, R., and Rindler, W. 1987. *Spinors and Space-Time, vol. 1*. Cambridge Monographs on Mathematical Physics. Cambridge: Cambridge University Press.
[128] Peskin, M. E., and Schroeder, D. V. 1995. *An Introduction to Quantum Field Theory*. Reading, MA: Addison-Wesley Publishing Company Advanced Book Program.
[129] Radzikowski, M. J. 1996. Micro-local approach to the Hadamard condition in quantum field theory on curved space-time. *Commun. Math. Phys.*, **179**(3), 529–553.
[130] Rauch, J. 1991. *Partial Differential Equations*. Graduate Texts in Mathematics, vol. 128. New York: Springer-Verlag.
[131] Reed, M., and Simon, B. 1980. *Methods of Modern Mathematical Physics. I, Functional Analysis*. 2nd edn. New York: Academic Press Inc.
[132] Rejzner, K. 2016. *Perturbative Algebraic Quantum Field Theory*. Mathematical Physics Studies Springer.
[133] Rendall, A. D. 2008. *Partial Differential Equations in General Relativity*. Oxford Graduate Texts in Mathematics, vol. 16. Oxford: Oxford University Press.
[134] Rindler, W. 1991. *Introduction to Special Relativity*. 2nd edn. Oxford Science Publications. New York: The Clarendon Press, Oxford University Press.
[135] Ringström, H. 2009. *The Cauchy Problem in General Relativity*. ESI Lectures in Mathematics and Physics. Zürich: European Mathematical Society (EMS).
[136] Rudin, W. 1987. *Real and Complex Analysis*. 3rd edn. New York: McGraw-Hill Book Co.
[137] Rudin, W. 1991. *Functional Analysis*. 2nd edn. International Series in Pure and Applied Mathematics. New York: McGraw-Hill Inc.
[138] Sahlmann, H., and Verch, R. 2001. Microlocal spectrum condition and Hadamard form for vector-valued quantum fields in curved spacetime. *Rev. Math. Phys.*, **13**(10), 1203–1246. *arXiv:math-ph/0008029*.
[139] Sakurai, J. J., and Napolitano, J. 1994. *Advanced Quantum Mechanics*. 2nd edn. San Francisco: Addison-Wesley Publishing Company.
[140] Schubert, H. 1968. *Topology*. Boston, Mass: Allyn and Bacon, Inc., Translated from the German by Siegfried Moran.
[141] Schwabl, F. 2002. *Quantum Mechanics*. 3rd edn. Berlin: Springer-Verlag.
[142] Strang, G. 1980. *Linear Algebra and Its Applications*. 2nd edn. New York-London: Academic Press.
[143] Taylor, M. E. 1996. *Partial Differential Equations. I*. Applied Mathematical Sciences, vol. 115. New York: Springer-Verlag.
[144] Taylor, M. E. 1997. *Partial Differential Equations. III*. Applied Mathematical Sciences, vol. 117. New York: Springer-Verlag.
[145] Taylor, M. E. 2011. *Partial Differential Equations. II*. 2nd edn. Applied Mathematical Sciences, vol. 116. New York: Springer.
[146] Thaller, B. 1992. *The Dirac Equation*. Texts and Monographs in Physics. Berlin: Springer-Verlag.
[147] Weinberg, S. 1996. *The Quantum Theory of Fields, vol. I*. Cambridge: Cambridge University Press. Foundations, Corrected reprint of the 1995 original.
[148] Finster F., Murro S., and Schmid G. 2025. The Cauchy problem for symmetric hyperbolic systems with nonlocal potentials. *arXiv:2507.05004 [math.AP]*.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 12 Nov 2026 at 10:19:45, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009632638