

And yet it moves: the momentum of static electromagnetic fields

P.G.L. Porta Mana 

Western Norway University of Applied Sciences <pgl@portamana.org>

13 November 2025; updated 13 November 2025 [draft]

1 Momentum in “static” electromagnetic configurations

That a “static” electromagnetic field configuration can have non-zero momentum is today no longer a matter of discussion, with plenty of experimental evidence and theoretical analyses.¹

Bibliography

(“de X” is listed under D, “van X” under V, and so on, regardless of national conventions.)

Calkin, M. G. (1966): *Linear momentum of quasistatic electromagnetic fields*. Am. J. Phys. **34**¹⁰, 921–925. doi:10.1119/1.1972282.

Calkin, M. G. (1971): *Linear momentum of the source of a static electromagnetic field*. Am. J. Phys. **39**⁵, 513–516. doi:10.1119/1.1986204.

Casserberg, B. R. (1982): *Electromagnetic momentum introduced simply*. Am. J. Phys. **50**⁵, 415–416. doi:10.1119/1.12827.

Coleman, S., Van Vleck, J. H. (1968): *Origin of “hidden momentum forces” on magnets*. Phys. Rev. **171**⁵, 1370–1375. doi:10.1103/PhysRev.171.1370.

Feynman, R. P., Leighton, R. B., Sands, M. (2010): *The Feynman Lectures on Physics. Vol. II: Mainly Electromagnetism and Matter*, new millennium ed. (Basic Books, New York). <https://www.feynmanlectures.caltech.edu/>. First publ. 1964.

Furry, W. H. (1969): *Examples of momentum distributions in the electromagnetic field and in matter*. Am. J. Phys. **37**⁶, 621–636. doi:10.1119/1.1975729.

Gralla, S. E., Lobo, K. (2022): *Electromagnetic scoot*. Phys. Rev. D **105**⁸, 084053. doi:10.1103/PhysRevD.105.084053. Updated version at arXiv doi:10.48550/arXiv.2112.01729.

¹ Page & Adams 1945; Feynman, Leighton, et al. 2010 Ch. 27; Pugh & Pugh 1967; Furry 1969; Calkin 1971; Wallace & O’Connell 1980; Casserberg 1982; Sharma 1988; Narayan 2021; Gralla & Lobo 2022; see also Poynting 1905; Page 1958 § 158; Jones & Richards 1954; Calkin 1966; Coleman & Van Vleck 1968; Scanio 1975; McDonald 2015; Majcen, Haaland, et al. 2000; McDonald 2003; 2019; Harbola 2010; Griffiths 2012; Morris & Styer 2012; McDonald 2022.

- Griffiths, D. J. (1989): *Note on "Field versus action-at-a-distance in a static situation"*. Am. J. Phys. **57**⁶, 558. doi:10.1119/1.15976. See Sharma 1988.
- Griffiths, D. J. (2012): *Resource letter EM-1: Electromagnetic momentum*. Am. J. Phys. **80**¹, 7–18. doi:10.1119/1.3641979.
- Harbola, M. K. (2010): *Energy flow from a battery to other circuit elements: role of surface charges*. Am. J. Phys. **78**¹¹, 1203–1206. doi:10.1119/1.3456567.
- Jones, R. V., Richards, J. C. S. (1954): *The pressure of radiation in a refracting medium*. Proc. R. Soc. Lond. A **221**¹¹⁴⁷, 480–498.
- Majcen, S., Haaland, R. K., Dudley, S. C. (2000): *The Poynting vector and power in a simple circuit*. Am. J. Phys. **68**⁹, 857–859. doi:10.1119/1.1302733.
- McDonald, K. T. (2003): *Hidden momentum in a coaxial cable*. arXiv doi:10.48550/arXiv.p hysics/0312028.
- McDonald, K. T. (2015): *The force on an antenna array*. <http://kirkmcd.princeton.edu/examples>. First publ. 1979.
- McDonald, K. T. (2019): *Four expressions for electromagnetic field momentum*. <http://kirkmcd.princeton.edu/examples>. First publ. 2006.
- McDonald, K. T. (2022): *Electromagnetic-field angular momentum of a classical charged particle in a uniform magnetic field*. http://kirkmcd.princeton.edu/examples/field_l.pdf.
- Morris, N. A., Styer, D. F. (2012): *Visualizing poynting vector energy flow in electric circuits*. Am. J. Phys. **80**⁶, 552–554. doi:10.1119/1.3679838.
- Narayan, O. (2021): *Momentum conservation in the Biot-Savart law*. Am. J. Phys. **89**¹¹, 1033–1036. doi:10.1119/10.0005207.
- Page, L. (1958): *Introduction to Theoretical Physics*, 3rd ed., 3rd pr. (Van Nostrand, Princeton, USA). First publ. 1928.
- Page, L., Adams Jr., N. I. (1945): *Action and reaction between moving charges*. Am. J. Phys. **13**³, 141–147.
- Poynting, J. H. (1905): *Note on the tangential stress due to light incident obliquely on an absorbing surface*. Philos. Mag. **49**, 169–171. doi:10.1080/14786440509463267.
- Pugh, E. M., Pugh, G. E. (1967): *Physical significance of the Poynting vector in static fields*. Am. J. Phys. **35**², 153–156. doi:10.1119/1.1973915.
- Scanio, J. J. G. (1975): *Conservation of momentum in electrodynamics – an example*. Am. J. Phys. **43**³, 258–260.
- Sharma, N. L. (1988): *Field versus action-at-a-distance in a static situation*. Am. J. Phys. **56**⁵, 420–423. doi:10.1119/1.15592. See also Griffiths 1989.
- Wallace, G. L., O'Connell, R. F. (1980): *Energy flow vector of the electromagnetic field*. Can. J. Phys. **58**⁶, 744–745. doi:10.1139/p80-101.