

References

Chapter 1

a) General

- Alfvén, H. (1981): *Cosmic Plasma* (D. Reidel, Dordrecht).
- Alfvén, H., Fälthammar, C.-G. (1963): *Cosmical Electrodynamics* (Oxford, London)
- Alfvén, H., Arrhenius, G. (1976): *Evolution of the Solar System* (NASA Publication SP-345, NASA, Washington D.C.)
- Bekefi, G. (1966): *Radiation Processes in Plasmas* (Wiley, New York)
- Jursa, A.S. (1985): *Handbook of Geophysics and the Space Environment* (National Technical Information Service, U.S. Department of Commerce, Springfield, VA)
- Krall, N.A., Trivelpiece, A.W. (1973): *Principles of Plasma Physics* (McGraw-Hill, New York)
- Lang, K. (1974): *Astrophysical Formulae* (Springer, New York, Heidelberg, Berlin)
- Lui, A.T.Y. (ed.) (1987): *Magnetotail Physics* (The Johns Hopkins University Press, Baltimore)
- Lyons, L.R., Williams, D.J. (1984): *Quantitative Aspects of Magnetospheric Physics* (D. Reidel, Dordrecht)
- Miller, R. B. (1982): *Intense Charged Particle Beams* (Plenum, New York)
- Nishida, A. (1988): *Magnetospheric Plasma Physics* (D. Reidel, Dordrecht, Holland)
- Priest, E. R. (1985): *Solar System Magnetic Fields* (D. Reidel, Dordrecht, Holland)
- Rose, D. J., Clark, M. (1961): *Plasmas and Controlled Fusion* (MIT Press, Cambridge, MA)

b) Special

- Alfvén, H. (1950): *Cosmical Electrodynamics* (Oxford University Press, New York)
- Alfvén, H., Wernholm, O. (1952): "A new type of accelerator," *Ark. För Fys.* **15** 175
- Akasofu, S.-I. (1981): "Energy coupling between the solar wind and the magnetosphere", *Space Sci. Rev.* **28** 121
- Bennett, W.H. (1934): "Magnetically self-focussing streams", *Phys. Rev.* **45** 890
- Berlin, A.B., Bulaenko, E.N., Vitkivskii, V.V., Pariiskii, Yu.N., Petrov, Z.E. (1983): "Search for small scale anisotropy of the 3K emission of the universe", in Abell and Chincarini (eds) *Early Evolution of the Universe and its Present Structure* (IAU Symposium 104, Kolymbari, Greece), pp.121-124
- Block, L.P., Fälthammar, C.-G. (1969): "Field-aligned currents and auroral precipitation", in *Atmospheric Emissions*, ed. by B.M. McCormac (Van Nostrand Reinhold Company), p. 285
- Book, D. L. (1987): *Plasma Formulary*, NRL Publication 0084-4040 (Naval Research Laboratory, Washington DC)
- Borucki, W. J. (1989): "Planetary lightning: a short review of extraterrestrial lightning characteristics," in *Laboratory and Space Plasmas*, ed. by H. Kikuchi (Springer, Berlin, Heidelberg)
- Bostick, W.H. (1986): "What laboratory-produced plasma structures can contribute to the understanding of cosmic structures both large and small", *IEEE Trans. Plasma Sci.* **1** 703
- Brecker (1984): "The quadrupole anisotropy", *Phys. Today* **37**

- Bridle, A.H. (1967): "The spectrum of the radio background between 13 and 404 MHz", *Mon. Not. R. Astro. Soc.* **136** 219
- Brown, W. C., Ness, W. N., Van Allen, J. A. (1963): "Collected papers on the artificial radiation belt from the July 9, 1962, nuclear detonation", *J. Geophys. Res.* **68** 605
- Buneman, O., Levy, R.H., Linson, L.M. (1966): "Stability of crossed-field electron beams," *J. Appl. Phys.* **37** 3203
- Chandrasekhar, S. (1961): *Hydrodynamic and Hydromagnetic Stability* (Clarendon Press, Oxford)
- Collins, G.B. (1948): *Microwave Magnetrons* (McGraw-Hill, New York)
- Dennis, B., Canfield, R. (1988): *Max '91* (NASA Goddard Space Flight Center, Greenbelt, Maryland)
- Destler, W.W., Hoerberling, R.F., Kim, H., Bostick, W.H. (1979): "Collective acceleration of carbon ions to 170 MeV," *Appl. Phys. Lett.* **35** 296
- Eastman, T. (1990): "Transition regions in solar system and astrophysical plasmas," *IEEE Trans. Plasma Sci.* **18** 18
- Faehl, R. J., Godfrey, B. B. (1978): "Collective ion acceleration through temporal modulation of relativistic-electron beam energy," *Phys. Rev. Lett.* **40** 1137
- Fälthammar, C.-G. (1990): "Electrodynamics of Cosmical Plasmas—Some basic aspects of cosmological importance", *IEEE Trans. Plasma Sci.* **18** 11
- Felch, K.L. (1985): "Introduction to the special issue on high-power microwave generation", *IEEE Trans. on Plasma Sci.* **13** 361
- Godfrey, B.B., Thode, L. E. (1975): "Collective ion acceleration via the two-stream instability", *New York Acad. Sci.* **251** 582
- Kaiser, M.L., Desch, M.D. (1984): "Radio emissions from the planets Earth, Jupiter, and Saturn," *Rev. Geophys. and Space Phys.* **22** 373
- Katsouleas, T. (1987): "Introduction to the special issue on plasma-based high-energy accelerators," *IEEE Trans. Plasma Sci.* **15** 85
- Luce, J.S. (1975): "Neutrons and radioisotopes produced by collective effect acceleration", *Ann. New York Acad. Sci.* **251** 217
- Moran, P. (1984): "Masers in the nuclei of galaxies", *Nature* **310** 270
- Nahin, P.J. (1988): *Oliver Heaviside: Sage in Solitude* (IEEE Press, New York)
- Ness, W.N. (1963): "Collected papers on the artificial radiation belt from the July 9, 1962, nuclear detonation", *J. Geophys. Res.* **68** 605
- Peratt, A.L. (1985): "A high-power reflex triode microwave source", *IEEE Trans. on Plasma Sci.* **13** 498
- Periiskii, Y.N., Korolkov, D.V. (1986): "Experiment Cold: the first deep sky survey with the Ratan-600 radio telescope", *Sov. Sci. Rev. E. Astrophys. Space Phys.* **5** 39
- Reber, G. (1986): "Intergalactic plasma", *IEEE Trans. Plasma Sci.* **14** 678
- Shannahan, W. R., Faehl, R. J. (1981): "Collective ion acceleration," Los Alamos National Laboratory Report LA-8961-PR
- Suess, S. T., Dessler, A. J. (1985): "Probing the local interstellar medium," *Nature* **317** 702
- Willett, J.C., Bailey, J.C., Leteinturier, C., Krider, E.P. (1990): "Lightning electromagnetic radiation field spectra in the interval from 0.2 to 20 MHz, *J. Geophys. Res.* **95** 20,367
- Yusef-Zadeh, F., Morris, M., Chance, D. (1984): "Large, highly organized radio structures near the galactic centre", *Nature* **310** 557

c) Critical Ionization Velocity

- Alfvén, H. (1942): "On the cosmogony of the solar system", *Stockholms Observatoriums Annaler* I. 14 No. 2
- Brenning, N., Axnäs, I. (1988): "Critical ionization velocity interactions: Some unsolved problems", *Astrophys. Space Sci.* **144** 15
- Cloutier, P.A., Daniell, R.E., Dessler, A.J., Hill, T.J. (1978): "A cometary ionosphere model for Io", *Astrophys. Space Sci.* **55** 93
- Fahleson, U. (1961): "Experiments with plasma moving through neutral gas", *Phys. Fluids* **4** 123
- Fälthammar, C.-G. (1988): "Laboratory and near-earth space plasma as a key to the plasma universe", *Laser and Particle Beams* **6** 437
- Galeev, A.A. *et al* (1986): "Critical ionization velocity effects in the inner coma of Comet Halley: measurements by Vega-2", *Geophys. Res. Lett.* **13** 845
- Gold, T., Soter, S. (1976): "Cometary impact and the magnetization of the moon", *Planet. Space Sci.* **24** 45
- Haerendel, G. (1982): "Alfvén's critical velocity effect tested in space" *Zeitschrift für Naturforschung* **37a** 728
- Haerendel, G. (1986): "Plasma flow and critical velocity ionization in cometary comae", *Geophys. Res. Lett.* **13** 255
- Lai, S.T., Murad, E., McNeil, W.J. (1989): "An overview of atomic and molecular processes in critical velocity ionization", *IEEE Trans. Plasma Sci.* **17** 124
- Lindeman, R.A. *et al* (1974): "The interaction between an impact-produced neutral gas cloud and the solar wind at the lunar surface", *J. Geophys. Res.* **79** 2287
- Luhmann, J. (1988): "An assessment of the conditions for critical velocity ionization at the weakly ionized planets", the XXVIIIth COSPAR Meet. Helsinki, Finland, paper XIII.1.6
- Petelski, E.F., Fahr, H.J., Ripken, H.W., Brenning, N., Axnäs, I. (1980): "Enhanced interaction of the solar wind and the interstellar neutral gas by virtue of a critical velocity effect", *Astron. Astrophys.* **87** 20
- Petelski, E.F. (1981): "Viability of the critical ionization velocity concept in selected space situations" in *Relation Between Laboratory and Space Plasmas*, H. Kikuchi, Ed. (D. Reidel, Dordrecht, Holland)
- Singh, N. (1989): "Magnetic field-aligned plasma expansion in critical ionization velocity space experiments", *IEEE Trans. Plasma Sci.* **17** 124
- Torbet, R. (1988): "Review of ionospheric CIV experiments", XXVIIIth COSPAR Meet. Helsinki, Finland, paper XIII.2.1

Chapter 2

a) Birkeland Currents

- Alfvén, H. (1939): "Magnetic storms and the aurorae", *Proc. Royal Swedish-Academy of Sciences (Kungliga Svenska Vetenskapakademiens Handlingar)* **18** 139).
- Alfvén, H. (1977): "Electric currents in cosmic plasma," *Rev. Geophys. & Space Phys.* **15** 271
- Bhavsar, S.P., Ling, E.N. (1988): "Are the filaments real?", *Astrophys. J.* **331** L63

- Browne, P.F. (1986): "Magnetic vortex tubes in astrophysics", *IEEE Trans. Plasma Sci.* **14** 718
- Cummings, W., Dessler, A.J. (1967): "Field-aligned currents in the magnetosphere", *J. Geophys. Res.* **72** 1007
- Dessler, A. (1984): "Evolution of arguments regarding existence of field aligned currents," in *Magnetospheric Currents*, T.A. Potemra (ed.), Geophysical Monograph No. 28, American Geophysical Union, Washington, D.C.
- Egeland, A., Holtet, J. (1968): *The Birkeland Symposium on Aurora and Magnetic Storms* (Centre National de la Recherche Scientifique, Paris)
- Fälthammar, C.-G. (1986): "Magnetosphere-ionosphere interactions: near-earth manifestations of the plasma universe", *IEEE Trans. Plasma Sci.* **14** 616
- Hill, T.W. (1984): "Rotationally-induced Birkeland current systems," in *Magnetospheric Currents*, T.A. Potemra (ed.), Geophysical Monograph No. 28, American Geophysical Union, Washington, D.C., p.340
- Iijima, T., Potemra, T.A. (1976): "Field-aligned currents in the dayside cusp observed by Triad", *J. Geophys. Res.* **81** 5971
- Kim, K.-T., Kronberg, P.P., Giovannini, G., Venturi, T. (1989): "Discovery of intergalactic radio emission in the Coma-A1367 supercluster", *Nature* **341** 720
- Lerner, E.J. (1986): "Magnetic vortex filaments, universal scale invariants, and the fundamental constants", *IEEE Trans. Plasma Sci.* **14** 690
- Peratt, A.L., Green, J.C. (1983): "On the evolution of interacting magnetized galactic plasmas", *Astrophys. Space Sci.* **91** 19
- Peratt, A.L. (1986): "Evolution of the plasma universe 1. Double radio galaxies, quasars, and extragalactic jets", *IEEE Trans. Plasma Sci.* **14** 639
- Potemra, T.A. (1984): *Magnetospheric Currents* (Geophysical Monograph No. 28, Amer. Geophys. Union, Washington DC)
- Salingaros, N. (1988): "An amended magnetohydrodynamics equation which predicts field-aligned current sheets", *Astrophys. Space Sci.* **137** 385
- Zmuda, A.J., Martin, J.H., Huring, F.T. (1966): *J. Geophys. Res.* **71** 5033
- Zmuda, A.J., Huring, F.T., Martin, J.H. (1967): *J. Geophys. Res.* **72** 1115

b) Bennett Pinches

- Bennett, W.H. (1934): *Phys. Rev.* **45** 890
- Carlqvist, P. (1988): "Cosmic electric currents and the generalized Bennett Relation," *Astrophys. Space Sci.* **144** 73
- Meierovich, B.E. (1984): "Electromagnetic collapse, problems of stability, emission of radiation and evolution of a dense pinch", *Phys. Reports* **104** 259
- Murty, G.S. (1961): "Instability of a conducting cylinder in the presence of an axial current, a longitudinal magnetic field and a coaxial conducting cylinder", *Arkiv för Fysik* **19** 483
- Nielsen, D., Green, J., Buneman, O. (1979): "Dynamic evolution of a z-pinch", *Phys. Rev. Lett.* **42** 1274
- Peratt, A.L., Green, J., Nielsen, D. (1980): "Evolution of colliding plasmas," *Phys. Rev. Lett.* **44** 1767
- Pereira, N.R., Davis, J., Rostocker, N. (eds) (1989): *Dense Z-Pinches* (American Institute of Physics, New York)

Witalis, E. (1986): "Hall magnetohydrodynamics and its applications to laboratory and cosmic plasma", *IEEE Trans. on Plasma Sci.* **14** 842

Witalis, E. (1981): *Phys.Rev.A* **24** 2758

c) Diocotron, Beam, and Plasma Instabilities

Alfvén, H. (1951): *Cosmical Electrodynamics* (Oxford, London), p. 206

Bostick, W.H. (1956): "Experimental study of ionized matter projected across a magnetic field", *Phys. Rev.* **104** 292

Bostick, W.H. (1957): "Simulation of astrophysical processes in the laboratory", *Nature* **179** 214

Bostick, W.H., Prior, W., Grunberger, L., Emmert, G. (1966): *Phys. Fluids* **9** 2078

Buneman, O. (1949): "A toroidal magnetron," *Proc. Phys. Soc. London* **1363** 278

Buneman, O. (1957): "Ribbon beams," *J. Electronics and Control* **3** 507

Buneman, O., Levy, R. H., Linson, L. M. (1966): "Stability of crossed-field electron beams," *J. Appl. Phys.* **37** 3203

Carmel, Y., Nation, J. A. (1973): "Instability of an unneutralized relativistic electron beam," *Phys. Rev. Lett.* **31** 286

Cutler, C. C. (1956): "Instability in hollow and strip electron beams," *J. Appl. Phys.* **27** 1028

Davis, T. N., Hallinan, T. J. (1976): "Aurora spirals 1. Observations," *J. Geophys. Res.* **81** 3953

Ekdahl, C.A., Freeman, J.R., Leifste, G.T., Miller, R.B., Stygar, W.A., Godfrey, B.B. (1985): "Axisymmetric hollowing instability of an intense relativistic electron beam propagating in air", *Phys. Rev. Lett.* **55** 935

Friedman, M., Hammar, D. A. (1972): "Catastrophic disruption of the flow a magnetically confined intense relativistic electron beam," *Appl. Phys. Lett.* **21** 174

Fälthammar, C.-G. (1986): "Magnetosphere-ionosphere interactions—near-earth manifestations of the plasma universe," *IEEE Trans. Plasma Sci.* **14** 616

Hallinan, T. J. (1970): "Small scale arc distortions," *Planet. Space Sci.* **18** 1735

Hallinan, T. J. (1976): "Aurora spirals 1. Theory," *J. Geophys. Res.* **81** 3959

Hammer, D.A., Rostocker, N. (1970): *Phys. Fluids* **13** 1831

Ivanov, V. S., Kremmentsov, S. I., Raizer, M. D., Rukhadze, A. A., Fedotov, A. V. (1981): *Sov. J. Plasma Phys.* **7** 430

Jones, M. E., Mostrom, M. A. (1981): "The diocotron instability in annular relativistic electron beams," *J. Appl. Phys.* **52** 3794

Kapetanacos, C. A. (1974): "Filamentation of intense electron beams propagating in dense plasmas," *Appl. Phys. Lett.* **25** 484

Kapetanacos, C. A., Hammer, D. A., Striffler, C. D., Davidson, R. C. (1973): "Destructive instabilities in hollow intense relativistic electron beams," *Phys. Rev. Lett.* **30** 1303

Knauer, W. (1966): "Diocotron instability in plasmas and gas discharges," *J. Appl. Phys.* **37** 602

Knauer, W., Poeschel, J. L. (1966): "The diocotron effect in plasmas and gas discharges," in *Phenomena. in Ionized Gases*, Perovic, B. and Tosic, D. (eds) (Gradeviska Knjiga Publ., Beograd) p.719

Küppers, G., Salat, A., Wimmel, H.K. (1973): "Macroscopic equilibria of relativistic electron beams in plasmas", *Plasma Phys.* **15** 441

Kyhl, R. L., Webster, H. F. (1956): "Breakup of hollow cylindrical electron beams," *IRE Trans. Prof. Group on Electron Devices ED-3* 183

- Lehnert, B. (1952): "Experiments on non-laminar flow of mercury in presence of a magnetic field," *Tellus* 4 63
- Lehnert, B. (1955): "An instability of laminar flow of mercury caused by an external magnetic field," *Proc. Roy. Soc. A* 233 299
- Levy, R. H. (1965): "Diocotron instability in a cylindrical geometry," *Phys. Fluids* 8 1288
- Levy, R. H., Hockney, M. A. (1968): "Computer experiments on low-density crossed-field electron beams," *Phys. Fluids* 11 766
- Mostrom, M. A., Jones, M. E. (1983): "Shear-driven instabilities of annular relativistic electron beams in vacuum," *Phys. Fluids* 26 1649
- Nardi, V., Bostick, W. H., Feugeas, J., Prior, W. (1980): "Internal structure of electron-beam filaments," *Phys. Rev. A* 22 2211
- Peratt, A. L., Snell, C.M. (1985): "Microwave generation from filamentation and vortex formation within magnetically confined electron beams," *Phys. Rev. Lett.* 54 1167
- Pierce, J.R. (1956): "Instability of hollow beams", *IRE Trans. on Electron Devices* ED-3 183
- Shrafranov, V.D. (1957): "On the stability of a cylindrical gaseous conductor in a magnetic field", *J. Nucl. Energy* 5 86
- Wagner, J.S., Sydora, R. D., Tajima, T., Hallinan, T., Lee, L. C., S. -I. Akasofu (1983): *J. Geophys. Res.* 88 8013
- Webster, H. F. (1955): "Breakup of hollow beams," *J. Appl. Phys.* 26 1386
- Webster, H. F. (1957): "Structure in magnetically confined electron beams," *J. Appl. Phys.* 28 1388
- Webster, H. F., Hallinan, T. J. (1973): "Instabilities in charge sheets and current sheets and their possible occurrence in the aurora," *Radio Sci.* 8 475
- Wollman, E.R. (1988): "A grain plasma model of galaxies", *Laser and Particle Beams* 6 545
- Yu, S. P., Kooyers, G. P., Buneman, O. (1965): "Time-dependent computer analysis of electron wave interaction in crossed fields," *J. Appl. Phys.* 36 2550

Chapter 3

a) General

- Elliot, R.S. (1966): *Electromagnetics* (McGraw-Hill, New York)
- Panofsky, W. K. H., Phillips, M. (1962): *Classical Electricity and Magnetism* (Addison-Wesley, Reading)
- Plonsey, R., Collin, R. E. (1961): *Principles and Applications of Electromagnetic Fields* (McGraw-Hill, New York)
- Smythe, W. R. (1950): *Static and Dynamic Electricity* (McGraw-Hill, New York)
- Stratton, J. A. (1941): *Electromagnetic Theory* (McGraw-Hill, New York)
- Tandberg-Hanssen, E., Emslie, A. G. (1988): *The Physics of Solar Flares* (Cambridge University Press, New York)

b) Magnetic Fields in Laboratory and Space Plasmas

- Acuña, M. H., Ness, N. F. (1975): "The Pioneer XI high field fluxgate magnetometer," *Space Sci. Instr.* **1** 177
- Bostick (1986): "What laboratory-produced plasma structures can contribute to the understanding of cosmic structures both large and small", *IEEE Trans. on Plasma Sci.* **14** 703
- Chandrasekhar, S., Kendall, P.C. (1957): "On force-free magnetic fields", *Astrophys. J.* **126** 457
- Gold, T. (1964): in *AAS-NASA Symposium on Physics of Solar Flares* (Hess, W.N., ed), p.389, NASA SP-50
- Felber, F.S., Peratt, A.L. (1980): "Self-similar oscillations of a Z pinch", *Bull. Am. Phys. Soc.* **25**
- Ferraro, V.C.A., Plumpton, C. (1966): *An Introduction of Magneto-Fluid Mechanisms* (Clarendon Press, Oxford)
- Nakagawa, J., Raadu, M.A. (1972): *Solar Phys.* **25** 127
- Peratt, A. L. (1986): "Evolution of the plasma universe I. Double radio galaxies, quasars, and extragalactic jets," *IEEE Trans. Plasma Sci.* **14** 639
- Peratt, A. L. (1986): "Evolution of the plasma universe II. The formation of systems of galaxies," *IEEE Trans. Plasma Sci.* **14** 763
- Stenzel, R.L., Gekelman, W. (1981): "Magnetic field reconnection experiments 1. Field topologies", *J. Geophys. Res.* **86** 649
- Thompson, J.E., Luessen. L.H. (Eds) (1986): *Fast Electrical and Optical Measurements. Vol. 1—Current and Voltage Measurements* (Martinus Nijhoff Publ., Dordrecht)
- Voigt G.-H. (1988): "Quasi static MHD processes in earth's magnetosphere," *Laser and Particle Beams* **6** 525
- Woltjer, L. (1958): "A theorem on force-free magnetic fields", *Proc. Nat. Acad. Sci.* **44** 489

c) Magnetic Fields in Galaxies

- Beck, R. (1986): "Interstellar magnetic fields", *IEEE Trans. Plasma Sci.* **14** 740
- Beck, R. (1990): "Magnetic fields in spiral galaxies", *IEEE Trans. Plasma Sci.* **18** 33
- Bosma, A., van de Hulst, J.M, Sullivan III, W.T. (1977): "A neutral hydrogen study of the spiral galaxy NGC 4736", *Astron. Astrophys.* **57** 373
- Bosma, A. (1981): "21-cm line studies of spiral galaxies. I. Observations of the galaxies NGC 5033, 3198, 5055, 2841, and 7331" *Astron. Astrophys.* **86** 1791
- Bosma, A. (1981): "21-cm line studies of spiral galaxies. II. The distribution and kinematics of neutral hydrogen in spiral galaxies of various morphological type" *Astron. Astrophys.* **86** 1825
- Bosma, A., Ekers, R.D., Lequeux, J., (1977): "A 21-cm study of the Seyfert galaxy NGC 4151", *Astron. Astrophys.* **57** 97
- Crutcher, R. M., Kazés, I. (1983): *Astron. Astrophys.* **125** L23
- Davis, L., Greenstein, J.L. (1951): *Astrophys. J.* **114** 206
- Fiebig, D., Güsten, R. (1988): "Strong magnetic fields in interstellar H₂O maser clumps", *Astron. Astrophys.*
- Fujimoto, M. (1987): "Bisymmetric spiral magnetic fields in spiral galaxies", in *Interstellar Magnetic Fields*, R. Beck and R. Gräve (eds) (Springer Verlag, Berlin)
- Harnet, J.I. (1984): *Mon. Notic. Roy. Astron. Soc.* **210** 12
- Heiles, C. (1976): *Ann. Rev. Astron. Astrophys.* **14** 1

- Heiles, C., Chu, Y.H., Troland, T.H. (1981): *Astrophys. J.* **247** L77
- Hummel, E., Bosma, A. (1982): "Radio continuum observations of the spiral galaxies NGC 2841, NGC 5055, and NGC 7331", *Astron. J.* **87** 242
- Kaplan, S.A., Pikelner, B. (1970): *The Interstellar Medium* (Harvard University Press, Cambridge, MA)
- Kim, K.-T., Kronberg, P.P., Giovannini, G., Venturi, T. (1989): "Discovery of intergalactic radio emission in the Coma-A1367 supercluster", *Nature* **341** 720
- Krause, M., Hummel, E., Beck, R. (1989): "The magnetic field structure in two nearby galaxies. I. The axisymmetric spiral magnetic field in IC 342", *Astron. Astrophys.* **217** 4
- Krause, M., Beck, R., Hummel, E. (1989): "The magnetic field structure in two nearby galaxies. I. The bisymmetric spiral magnetic field in M81", *Astron. Astrophys.* **217** 17
- Peratt, A.L., Green, J.C. (1983): "On the evolution of interacting magnetized galactic plasmas", *Astrophys. Space Sci.* **91** 19
- Peratt, A.L. (1984): "Simulating spiral galaxies", *Sky Telesc.* **68** 118
- Peratt, A.L. (1986): "Evolution of the plasma universe: II. The formation of systems of galaxies", *IEEE Trans. Plasma Sci.* **14** 763
- Peratt, A.L. (1990): "3-dimensional particle-in-cell simulations of spiral galaxies", in *IAU Symp.* **140**, R. Beck (ed)
- Phillips, S. Kearsy, S., Osborne, J.L., Haslam, C.G.T., Stoffel, H. (1981): *Astron. Astrophys.* **98** 286
- Reich, W. (1988): "Observations of linear polarization at 32 GHz of the galactic center arc" in *The Galactic Center*, M. Morris (ed) (D. Reidel, Dordrecht)
- Rogstad, D.H., Lockart, I.A., Wright, M.C.H. (1974): "Aperture synthesis observations of the HI in the galaxy M85" *Astrophys. J.* **193** 309
- Seiradakis, J.H., Lasenby, A.N., Yusef-Zadeh, F., Wielebinski, R., Klein, U. (1985): "A new symmetrical polarization structure near the galactic center", *Nature* **317** 697
- Sofue, Y., Fujimoto, M., Wielebinski, R. (1986): "Global structure of magnetic fields in spiral galaxies", *Ann. Rev. Astron. Astrophys.* **24** 459
- Sofue, Y., Fujimoto, M. (1983): "A bisymmetric spiral magnetic field and the spiral arms in our galaxy", *Astrophys. J.* **265** 722
- Spoelstra, T.A.T. (1977): *Sov. Phys.—Usp.* **20** 336
- Vallée, J.P. (1988): "Can the large-scale magnetic field lines cross the spiral arms in our Milky Way galaxy?", *Astron. J.* **95** 750
- Van Woerden, H. Van Driel, W., Schwarz, U. J. (1983): "Distribution and motions of atomic hydrogen in lenticular galaxies", in *Internal Kinematics and Dynamics of Galaxies*, E. Athanassoula (ed) (American Astron. Union, Washington D.C.), 99
- Verschuur, G.L. (1979): *Fund. Cosmic Phys.* **5** 113
- Verschuur, G.L. (1987): "The strength of the interstellar magnetic field and its possible role in HI cloud dynamics", in *Interstellar Magnetic Fields*, (eds) R. Beck, R. Gräve (Springer-Verlag, Berlin) 154
- Wielebinski, R. (1989): "Magnetic fields in the galaxy", Max-Planck-Institut für Radioastronomie preprint series no. 347
- Yusef-Zadeh, F., Morris, M., Chance, D. (1984): "Large, highly organized radio structures near the galactic centre", *Nature* **310** 557

Chapter 4

a) General

- Alfvén, H. (1960): *On the Origin of the Solar System* (Oxford University Press, New York). See also Rev. Mod. Phys. **32** 710
- Alfvén, H., Fälthammer, C.-G. (1963): *Cosmic Electrodynamics* (Oxford University Press, New York)
- Alfvén, H. (1981): *Cosmic Plasma* (D. Reidel Publ. Co., Dordrecht, Holland) Chap. IV
- Fälthammar, C.-G. (1977): "Problems related to macroscopic electric fields in the magnetosphere," Rev. Geophys. Space Phys. **15** 457
- Helliwell, R. A. (1967): *Whistlers and Related Ionospheric Phenomena* (Stanford Univ. Press, Stanford)
- Lyons, L. R., Williams, D.J. (1984): *Quantitative Aspects of Magnetospheric Physics* (D. Reidel, Dordrecht, Holland). Chap. 4
- Müller, R.B. (1982): *Intense Charged Particle Beams* (Plenum, New York) Chap.1

b) Special

- Acuna, M.H., Neubauer, F. M., Ness, N.F.(1981): J. Geophys. Res. **86** 8513
- Alfvén, H. (1958): in Proceedings of the 2nd Int. Conf. on Peaceful Uses of Atomic Energy (United Nations, Geneva) **31** 3
- Block, L. P., Fälthammar, C.-G., Lindqvist, P.-A., Markalund, G., Mozer, F. S., Pedersen, A., Potemra, T. A., Zanetti, L. J. (1987): "Electric field measurements on Viking: first results," Geophys. Res. Lett. **14** 435
- Colgate, S. (1990): "E-parallel acceleration of cosmic rays, twisted magnetic fields, and collimated radio sources", Los Alamos Astrophysics Seminar, December 5, 1990.
- Cook, A.F., Shoemaker, E.M., Smith, B.A., Danielson, G.E., Johnson, T.V., Synnott, S. P. (1981): Science **211** 1419
- Fälthammar, C.-G. (1978): "Generation mechanisms for magnetic-field-aligned electric fields in the magnetosphere," J. Geomag. Geoelectr. **30** 419
- Fälthammar, C.-G. (1979): "Non-resistive electric potential drops in cosmical plasmas," in *Particle Acceleration Mechanisms in Astrophysics*, ed. by J. Arons, C. McKee, C. Max (Amer. Inst. Phys., New York)
- Fälthammar, C.-G. (1983): "Magnetic-field-aligned electric fields," ESA Journal **7** 385.
- Fälthammar, C.-G. (1988): "Laboratory and near-earth space plasmas as a key to the plasma universe," Laser and Particle Beams **6** 437
- Fälthammar, C.-G., Block, L. P., Lindqvist, P.-A., Marklund, G., Pedersen, A., Mozer, F. S. (1987): "Preliminary results from the d.c. electric field experiment of Viking," Annales Geophys. **5A** 171
- Garscadden, A. (1986): "Rydberg states: Properties and applications to electrical discharge measurements," in *Radiative Processes in Discharge Plasmas*, ed. by J.M. Proud and L.H. Leussen (Plenum Publ. Co.)

- Geller, R., Hopfgarten, N., Jacquot, B., Jacquot, C. (1974): "Electric fields parallel to the magnetic field in laboratory plasma in a magnetic mirror field", *J. Plasma Phys.* **12** 467
- Gold, T. (1979): *Science* **206** 1071
- Knight, S. (1973): "Parallel electric fields", *Planet. Space Sci.* **21** 741
- Lemaire, J., Scherer, M. (1974): "Ionosphere plasma-sheet field-aligned currents and parallel electric fields", *Planet. Space Sci.* **22** 1485
- Lemaire, J., Scherer, M. (1983): *Annales Geophysicue* **1** 91
- Lundin, R., Sandahl, J. (1978): *ESA Special Publication SP-135* 125
- Marklund, G.T. (1979): "Plasma convection in force-free magnetic fields as a mechanism for chemical separation in cosmical plasmas", *Nature* **277** 370
- Marklund, G.T., Blomberg, L.G., Hardy, D.A., Rich, F.J. (1987): "Instantaneous pictures of the high-latitude electrodynamic using Viking and DMSP/F7 observations", in *Proc. 8th ESA Symp. (Sunne, Sweden) ESA SP-270*, 45
- Marklund, G., Block, L., Lindqvist, P.-A. (1981): "Rocket measurements of electric fields, electron density and temperature during different phases of auroral substorms," *Planet. Space Sci.* **29** 249
- Mauk, B.H., Zanetti, L.J. (1987): "Magnetospheric electric fields and currents," *Rev. of Geophys.* **25** 541
- Melzner, F., Metzner, G., Antrack, D. (1978): "The Geos electron beam experiment S 329," *Space Sci. Instr.* **4** 45
- Mirabel, I.F., Morras, R. (1984): "Evidence for high velocity inflow of neutral hydrogen toward the galaxy", *Astrophys. J.* **279** 86
- Morabite, L.A., Synnott, S.P., Kupferman, P.N., Collins, S.A. (1979): *Science* **204** 972
- Mozer, F.S. et al (1980): "Satellite measurements and theories of low altitude auroral particle acceleration", *Space Sci. Rev.* **27** 155
- Pedersen, A., Cattell, C. A., Fälthammar, C.-G., Formisano, V., Lindqvist, P.-A., Mozer, F., Torbert, R. (1984): "Quasistatic electric field measurements with spherical double probes on the Geos and ISEE satellites," *Space Sci. Reviews* **37** 269
- Peratt, A.L., Dessler, A.J. (1988): "Filamentation of volcanic plumes on the Jovian satellite Io", *Astrophys. Space Sci.* **144** 451
- Richmond, A. D. (1986): "Upper-atmosphere electric-field sources," in *The Earth's Electrical Environment* (National Academy Press, Washington DC), p.195
- Smith, B.A. et al. (1979): *Science* **204** 945.
- Smith, B.A., Shoemaker, E.M., Kieffer, S.W., Cook, A.F. (1979): *Nature* **280** 738
- Southwood, D. J., Kivelson, M.G., Walker, R.J., Slavin, J.A. (1980): *J. Geophys. Res.* **85** 5959
- Strom, R.G., Terrile, R.J., Masursky, H., Hansen, C. (1979): *Nature* **280** 733
- Strom, R.G., Schneider, N.M. (1982): in D. Morrison (ed.) *Satellites of Jupiter* (Univ. Arizona Press, Tucson, Arizona) 598
- Yariv, A. (1985): *Optical Electronics* (Holt, Rinehart, and Winston, New York)
- Zanetti, Jr., L. J., Arnoldy, R. J., Cahill, Jr., L. J., Behm, D. A., Greenwald, R. A. (1980): "Comparative rocket observations of ionospheric electric fields in the auroral oval," *Space Sci. Instr.* **5** 183

c) Dense Plasma Focus

- Alfvén, H., Wilcox, J.M. (1962): *Astrophys. J.* **136** 1016
- Borowiecki, M. *et al* (1981): "Investigation of the breakdown and run-down phases of the dense plasma focus discharge". S. Kaliski Institute of Plasma Physics and Laser Microfusion, Report No. 14/81 (74), Warsaw, Poland.
- Borowiecki, M. *et al* (1983): "The dynamics and plasma sheath structure in the plasma focus device". S. Kaliski Institute of Plasma Physics and Laser Microfusion, Report No. 3/83 (94), Warsaw, Poland.
- Bostick, W.H., Nardi, V., Prior, W. (1975): *Annals New York Academy of Sciences* **251** 2
- Dattner, A., Eninger, J. (1964): *Phys. of Fluids Suppl.* **7** S41
- Filippov, N.V., Filippova, T.I., Vinogradov, V. P. (1962): *Nucl. Fusion Suppl.*, Pt. 2
- Graton, F.T., Nardi, V., De Chiara, P., Gnani, G. (1990): "On the possibility of chaotic motion and acceleration of ions in oscillating plasma structures", *Contributed Papers, IV Latin American Workshop on Plasma Physics*, Buenos Aires, July 1990
- Lerner, E.J. (1986): "Magnetic self-compression in laboratory plasmas, quasars and radio galaxies", *Laser and Particle Beams* **4** part 2, 193
- Lindberg, L., Witalis, E., Jacobsen, C.T. (1960): *Nature* **185** 452
- Lindberg, L., Jacobsen, C. T. (1961): *Astrophys. J.* **133** 1043
- Lindberg, L., Jacobsen, C.T. (1964): *Phys. of Fluids Suppl.* **7** S44
- Mather, J. W. (1971): in Lovberg, R.H., Griem, H.R., *Plasma Physics* (Academic Press, New York) Chap.15

Chapter 5

- Akasofu, S.-I. (1988): "An electric-current description of solar flares", *Astrophys. Space Sci.* **144** 303
- Alfvén, H. (1958): *Tellus* **10** 104
- Alfvén, H. (1986): "Double layers and circuits in astrophysics," *IEEE Trans. Plasma Sci.* **14** 779
- Babić, M. *et al* (1971): *Tenth International Conference on Phenomena in Ionized Gases*, Oxford
- Bernstein, I. B., Greene, J. M., Kruskal, M. D. (1957): "Exact nonlinear plasma oscillations", *Phys. Rev.* **108** 546
- Biskamp, D., Chodura, R. (1971): *Phys. Rev. Lett.* **23** 1553
- Block, L. P. (1978): "A double layer review," *Astrophys. Space Sci.* **55** 59
- Bohm, M., Torven, S. (1987): *Inter. Conf. Plasma Phys. (Kiev)*, TRITA-EPP-86-11, Roy. Inst. Tech., Stockholm, Sweden
- Boris, J.P., Dawson, J.M., Orens, J.H., Roberts, K.V. (1970): "Computations on anomalous resistance", *Phys. Rev. Lett.* **25** 706
- Borovsky, J.E. (1984): "A review of plasma double-layer simulations," in *Second Symposium on Plasma Double Layers and Related Topics*, ed. by R. Schrittwieser and G. Eder (Innsbruck, Austria)
- Borovsky, J.E., Joyce, G. (1983): "Numerically simulated two-dimensional auroral double layers", *J. Geophys. Res.* **88** 3116

- Borovsky, J.E. (1984): "The production of ion conics by oblique double layers", *J. Geophys. Res.* **89** 2251
- Borovsky, J.E. (1988): "Production of auroral kilometric radiation by gyrophase-bunched double-layer-emitted electrons: Antennae in the magnetospheric current regions", *J. Geophys. Res.* **93** 5727
- Carlqvist, P. (1969): "Current limitation and solar flares," *Solar Phys.* **7** 377
- Carlqvist, P. (1972): "On the formation of double layers in plasmas," *Cosmic Electrodynamics* **3** 377
- Carlqvist, P. (1982): "On the physics of relativistic double layers," *Astrophys. Space Sci.* **87** 21
- Carlqvist, P. (1986): "On the acceleration of energetic cosmic particles by electrostatic double layers," *IEEE Trans. Plasma Sci.* **14** 794
- Carpenter, R.T., Torven, S. (1987): "The current-voltage characteristic and potential oscillations of a double layer in a triple plasma device", *Laser and Particle Beams* **5** 325
- Chupp, E.L. *et al* (1982): "A direct observation of solar neutrons following the 0118 UT flare on 1980 June 21", *Astrophys. J.* **263** L95
- Crawford, F.W., Freeston, I. L. (1963): *VIe Conférence Internationale sur les Phénomènes d'ionisation dans les Gaz*, Paris, Vol. I.
- Goertz, C.K., Joyce, G. (1975): *Astrophys. Space Sci.* **32** 165
- Goldsworthy, M. P., Green, F, Lalouis, P., Stening, R. J., Eliezer, S., Hora, H. (1986): "Hydrodynamic analysis of the high electric fields and double layers in expanding inhomogeneous plasmas," *IEEE Trans. Plasma Sci.* **14** 823
- Ichimaru, S. (1973): *Basic Principles of Plasma Physics* (W.A. Benjamin, Reading, MA)
- Jones, M.E., Gisler, G. (1986): *Bull. Am. Phys. Soc.* **31** 1398
- Kan, J. R., Akasofu, S.-I. (1989): "Electrodynamics of solar wind-magnetosphere-ionosphere interactions," *IEEE Trans. Plasma Sci.* **17** 83
- Langmuir, I. (1929): "The interaction of electron and positive ion space charges in cathode sheaths", *Phys. Rev.* **33** 954
- Lindberg, L. (1982): in *Proc. Symp. Plasma Double Layers*, P. Michersen and J. J. Rasmussen (eds) (Risø Nat. Lab., Roskilde, Denmark)
- Moreton, G.E., Severny, A.B. (1968): "Magnetic fields and flares in the region CMP, 20 September 1963", *Sol. Phys.* **3** 282
- Peratt, A.L., Jones, M.E. (1986): "Particle-in-cell simulations of heavy ion plasma double layers", *IEEE Conf. Rec., IEEE Int. Conf. Plasma Sci., Saskatoon, Canada.*
- Priest, E.R. (1982): *Solar MHD* (D. Reidel, Dordrecht)
- Raadu, M. A. (1989): "The physics of double layers and their role in astrophysics," *Phys. Reports* **178** 25
- Ryan, J.M., Chupp, E.L., Forrest, D.J., Matz, S.M., Rieger, E., Reppin, C., Kanbach, G., Share, G.H. (1983): *Astrophys. J.* **272** L61
- Sato, T., Okuda, H. (1981): *J. Geophys. Res.* **86** 3357
- Schönhuber, M. J. (1958): *Quecksilber-Niederdruck-Gasenladung* (Lachner, München)
- Severny, A.B. (1965): *Astron. Zh.* **42** 217
- Singh, N., Thiemann, H., Schunk, R.W. (1986): "Plasma processes driven by current sheets and their relevance to the auroral plasma", *IEEE Trans. on Plasma Sci.* **14** 805
- Tonks, L. (1958): *Trans. Electrochem.* **72** 167

- Vlasov, V.P., Zhdanov, S.K., Trubnikov, B.A. (1989): "Plasma pinch as a source of cosmic rays", *JETP Letters* **49** 667
- Williams, A. C. (1986): "General Bohm and Langmuir conditions for a strong double layer in space plasmas," *IEEE Trans. Plasma Sci.* **14** 800
- Williams, A. C. (1987): "Double Layers in Astrophysics", *Laser and Particle Beams* **5**
- Yamamoto, T., Kan, J.R. (1985): "The field-aligned scale length of one-dimensional double layers", *J. Geophys. Res.* **90** 1553

Chapter 6

a) General

- Bekefi, G. (1966): *Radiation Processes in Plasmas* (Wiley, New York)
- Ginzburg, V. L. (1961): *Propagation of Electromagnetic Waves in Plasma* (Gordon and Breach, New York)
- Ginzburg, V.L., Syrovatskii, S.I. (1965): "Cosmic magnetobrehmsstrahlung", *Ann. Rev. Astron. Astrophys.* **3**, 297
- Harrington, R. F. (1961): *Time-Harmonic Electromagnetic Fields* (McGraw-Hill, New York)
- Jackson, J. D. (1962): *Classical Electrodynamics* (Wiley, New York)
- Jones, D.S. (1964): *The Theory of Electromagnetism* (Pergamon Press, New York)
- Kellermann, K., Sheets, B. (eds) (1983): *Serendipitous Discoveries in Radio Astronomy* (National Radio Astronomy Observatory, Green Bank, West Virginia)
- Kraus, J. D. (1986): *Radio Astronomy* (Cygnus-Quasar Books, Powell, Ohio)
- Landau, L.D., Lifshitz, E.M. (1962): *The Classical Theory of Fields* (Pergamon, Oxford, London, Paris, Frankfurt). Chap. 9
- Pacholczyk, A.G. (1977): *Radio Galaxies* (Pergamon Press, New York)
- Panosofsky, W. K., Phillips, M. (1962): *Classical Electricity and Magnetism* (Addison-Wesley, Reading, MA)
- Rohlf, K. (1986): *Tools of Radio Astronomy* (Springer, Heidelberg, New York)
- Rose, D.J., Clark, M. (1961): *Plasmas and controlled fusion* (MIT Press, Cambridge, MA)
- Shklovsky, I.S. (1960): *Cosmic Radio Waves* (Harvard University Press, Cambridge), Chap. VI

b) Special

- Alfvén, H., Herlofson, N. (1950): *Phys. Rev.* **78** 616
- Baade, W., Minkowski, R. (1954): "Identification of the radio sources in Cassiopeia, Cygnus A, and Puppis A", *Astrophys. J.* **119** 206
- Benard, A. *et al* (1975): "Experimental studies of the plasma focus and evidence for nonthermal processes", *Phys. Fluids* **18** 180
- Bennett, W.H. (1934): "Magnetically self-focussing streams", *Phys. Rev.* **45** 890
- Burkhalter, P.G., Dozier, C.M., Nagel, D. J. (1977): "X-ray spectra from exploded-wire plasmas", *Phys. Rev. A* **15** 700
- Burkhalter, P.G., Davis, J., Rauch, J., Clark, W., Dahlbacka, G., Schneider, R. (1979): "X-ray line spectra from exploded-wire arrays", *J. Appl. Phys.* **50** 705

- Ekers, R.D. (1974): "Radio observations of the nuclei of galaxies", in *The Formation and Dynamics of Galaxies*, J.R. Shakeshaft, Ed. (IAU Symp. 58), p.257
- Epstein, R.L., Feldman, P.A. (1967): "Synchrotron radiation from electrons in helical orbits", *Astrophys. J.* **150** L109
- Gersten, M., Rauch, J.E., (1982): "Source size line broadening in convex curved crystal x-ray spectrographs", *J. Appl. Phys.* **53** 1297
- Ginzburg, V.L., Syrovatskii, S.I. (1965): "Cosmic Magnetobremstrahlung", *Ann. Rev. Astron. Astrophys.* **3** 297
- Ginzburg, V.L., Sazonov, V.N., Syrovatskii, S.I. (1968): "Synchrotron radiation and its reabsorption", *Sov. Phys. Uspekhi* **11** 34
- Ginzburg, V.L., Ozernoy, L.M. (1977): "On the nature of quasars and active galactic nuclei", *Astrophys. Space Sci.* **50** 23
- Hutchings, J.B. (1987): "What is the difference between radio galaxies and radio quasar galaxies?", *Astrophys. J.* **320** 122
- Johner, J. (1988): "Angular distribution of the total cyclotron radiation of a relativistic particle with parallel velocity", *Phys. Rev. A* **36** 1498
- Kai, K. (1965): "Polarization characteristics of type IV bursts", *Publ. Astron. Soc. Japan* **17** 294
- Kawabata, K. (1964): "Transfer of the gyro-resonance radiation", *Publ. Astron. Soc. Japan* **16** 30
- Lerner, E.J. (1986): Magnetic self compression in laboratory plasmas, quasars, and radio galaxies, Part I, II *Laser and Particle Beams* **4** 193
- Liang, E.P. (1989): "Gamma ray bursts: confrontation between theory and observational data", in *Proc. GRO Science Workshop*, W.N. Johnson (ed) (Naval Research Laboratory, Washington D.C.), p.4-397
- Mack, J.M., Peratt, A.L., Gisler, G.R. (1987): "Microwave signatures from circulating electron rings", *Bull. Am. Phys. Soc.* **32** 1721
- Meirovich, B.E. (1984): "Electromagnetic collapse, problems of stability, emission of radiation and evolution of a dense pinch", *Phys. Reports* **104** 259
- Miley, G. (1980): "The structure of extended extragalactic radio sources," *Ann. Rev. Astron. Astrophys.* **18** 165
- Moffet, A. T. (1975): "Strong nonthermal radio emission from galaxies", in *Galaxies and the Universe*, (eds) Sandage, Sandage, and Kristian (University of Chicago Press, Chicago)
- Newberger, B.S. *et al* (1984): "Synchrotron radiation from Bennett beams", *Bull. Amer. Phys. Soc.* **29** 1435
- Peratt, A.L., Green, J.C. (1983): "On the evolution of interacting magnetized, galactic plasmas", *Astrophys. Space Sci.* **91** 19
- Peratt, A.L., Koert, P. (1985): "Pulsed electromagnetic acceleration of exploded wire plasmas", *J. Appl. Phys.* **54** 6292
- Peratt, A.L. (1986): "Evolution of the plasma universe: I. Double radio galaxies, quasars, and extragalactic jets", *IEEE Trans. Plasma Sci.* **14** 639
- Peratt, A.L. (1988): "Particle beams and electrical currents in the plasma universe", *Laser and Particle Beams* **6** pt.3, 471
- Perola, G.C. (1981): "Radio galaxies: observations and theories of their extended components," *Fundamentals of Cosmic Phys.* **7** 59
- Reber, G. (1940): "Cosmic static", *Proc. IRE* **30** 367
- Reber, G. (1944): "Cosmic static", *Astrophys. J.* **100** 279

- Scheuer, P.A.G. (1968): "Synchrotron radiation formulae", *Astrophys. J.* **151** L139
- Schwinger, J. (1949): "On the classical radiation of accelerated electrons", *Phys. Rev.* **75** 1912
- Takakura, T. (1960): "Synchrotron radiation from intermediate energy electrons in helical orbits and solar radio bursts at microwave frequencies", *Publ. Astron. Soc. Japan* **12** 352
- Trubnikov, B.A. (1958): *Sov. Phys., 'Doklady'* **3** 136

Chapter 7

a) General

- Abramowitz, M., Stegun, I. (1965): *Handbook of Mathematical Functions* (Dover, New York)
- Bekefi, G. (1966): *Radiation Processes in Plasmas* (Wiley, New York)
- Reif, F. (1965): *Fundamentals of Statistical and Thermal Physics* (McGraw-Hill, New York)
- Sobolev, V.V. (1963): *A Treatise on Radiative Transfer* (D. Van Nostrand, Princeton)
- Stix, T. H. (1962): *The Theory of Plasma Waves* (McGraw-Hill, New York)

b) Special

- Crusius, A. (1988): "The influence of a thermal plasma on synchrotron radiation", *Laser and Particle Beams* **6** 421
- Crusius, A., Schlickeiser, R. (1986): "Synchrotron radiation in random magnetic fields", *Astron. Astrophys.* **164** L16
- Hirshfield, J.L., Bekefi, G. (1963): "Decameter radiation from Jupiter", *Nature* **198** 20
- Kimura, (1966): in Lyons, L. R., Williams, D. J. (1984): *Quantitative Aspects of Magnetospheric Physics* (D. Reidel, Dordrecht, Holland)
- Peratt, A.L., Kuehl, H.H. (1972): "Transmission and reflection of a wave obliquely incident on a nonuniform magnetized plasma", *Radio Sci.* **7** 309
- Peter, W., Peratt A. L. (1988): "Thermalization of synchrotron radiation from field-aligned currents", *Laser and Particle Beams* **6** 493
- Peter, W., Peratt A. L. (1990): "Synchrotron radiation spectrum for galactic-sized plasma filaments", *IEEE Trans. Plasma Sci.* **18** 49
- Storey, L.R.O. (1953): "An investigation of whistling atmospherics", *Phil. Trans. Roy. Soc. London Ser. A* **246** 113
- Trubnikov, B. A. (1958): "Plasma radiation in a magnetic field", *Sov. Phys. Doklady* **3** 136
- Trubnikov, B.A. (1961): "On the angular distribution of cyclotron radiation from a hot plasma", *Phys. Fluids* **4** 195
- Trubnikov, B.A., Yakubov, V.B. (1963): "Cyclotron radiation of electrons having a two-dimensional maxwellian distribution", *Plasma Phys.* **5** 7

Chapter 8

- Birdsall, C.K., Langdon, A.B. (1985): *Plasma Physics via Computer Simulation* (McGraw-Hill, New York)

- Birdsall, C.K. (1991): "Particle-in-cell charged particle simulations, plus Monte Carlo collisions with neutral atoms, PIC-MCC", IEEE Trans. Plasma Sci. **19**
- Boris, J.P., Dawson, J.M., Orens, J.H., Roberts, K.V. (1970): "Computations on anomalous resistance", Phys. Rev. Lett. **25** 706
- Bostick, W.H. (1958): "Possible hydromagnetic simulations of cosmical phenomena in the laboratory", Rev. Mod. Phys. **30** 1090
- Buneman, O. (1986): "Multidimensional particle codes: their capabilities and limitations for modeling space and laboratory plasma", IEEE Trans. Plasma Sci. **14** 661
- Buneman, O., Barnes, C.W., Green, J.C., Nielsen, D.E. (1980): "Principles and capabilities of 3D, EM particle simulations", J. Comp. Phys. **38** 1
- Cashwell, E.D., Everett, C.J. (1959): *Monte Carlo Method for Random Walk Problems* (Pergamon Press, New York)
- Hockney, R.W., Eastwood, J.W. (1981): *Computer Simulation Using Particles* (McGraw-Hill, New York)
- Karin, S., Smith, N.P. (1987): *The Supercomputer Era* (Harcourt, Brace, Jovanovich, Boston)
- Kwan, T.J.T., Snell, C.M., Mostrom, M.A., Mack, J.M., Hughes, H.G. (1985): "Monte Carlo charged particle and photon transport in particle-in-cell codes" in Eleventh International Conference on Numerical Simulation of Plasmas, Montreal, Canada 25-27 June 1985
- Langdon, A.B., Birdsall, C.K. (1970): Phys. Fluids **13** 2115
- Lehnert, B. (1959): "Plasma physics on cosmical and laboratory scale", Nuovo Cimento **13** (supplement) 59
- Lindman, E.L. (1970): J. Comp. Phys. **5** 13
- Nash, S. (1991): *History of Scientific Computation* (in press)
- Okuda, H., Birdsall, C.K. (1970): Phys. Fluids **13** 2123
- Okuda, H. (1972): Phys. Fluids **15** 1268
- Snell, C.M., Kwan, T.J.T., Morel, J.E., Witte, K.H. (1990): "Incorporation of atomic physics into particle simulations" Bull. Am. Phys. Soc. **35** 2001
- Störmer, C. (1955): *The Polar Aurora* (Clarendon Press, Oxford)

Appendix A

- Allis, W.P., Buchsbaum, S.J., Bers, A. (1963): *Waves in Anisotropic Plasmas* (MIT Press, Cambridge)
- Bekefi, G. (1966): *Radiation Processes in Plasmas* (Wiley, New York)
- Book, D.L. (1987): *NRL Plasma Formulary* (Naval Research Laboratory, Washington DC)
- Stix, T. H. (1962): *The Theory of Plasma Waves* (McGraw-Hill, New York)
- Swanson, G.D. (1989): *Plasma Waves* (Academic Press, New York)
- Westman, H.P. (ed.) (1960): *Reference Data For Radio Engineers* (International Telephone and Telegraph Corporation, New York). Chap. 20.

Appendix B

- Brown, R.G., Sharpe, R.A., Hughes, W.L. (1961): *Lines, Waves, and Antennas* (Ronald Press, New York)

- Fink, D.G., Christiansen, D. (eds) (1989): *Electronic Engineer's Handbook* (McGraw-Hill, New York). Chap. 9
- Motzer, G., Vabre, J.-P. (1969): *Transmission Lines with Pulse Excitation* (Academic Press, New York)
- Sato, T. (1978): "A theory of quiet auroral arcs", *J. Geophys. Res.* **83** 1042

Appendix C

- Alfvén, H., Arrhenius, G. (1976): *Evolution of the Solar System* (NASA publication SP-345, Washington, D.C.)
- Alfvén, H., Carlqvist, P. (1978): "Interstellar clouds and the formation of stars", *Astrophys. Space Sci.* **55** 484
- Azar, M.J., Thompson, W.B. (1989): "The role of dust particles with large gyroradii in the 2/3 fall-down process", *IEEE Trans. Plasma Sci.* **17** 228
- Deforest, S.E. (1972): *J. Geophys. Res.* **77** 651
- Gisler, G.R., Wollman, E.R. (1988): *Phys Fluids* **31** 1101
- Hill, J.R., Mendis, D.A. (1979): *Moon and the Planets* **21** 3
- Hill, J.R., Mendis, D.A. (1980): "Charged dust in outer planetary magnetospheres" *Moon and the Planets* **22**
- Horanyi, M., Goertz, C.K. (1990): "Coagulation of dust particles in a plasma", *Astrophys. J.* **361** 155
- Houpis, H.L.F., Whipple, E.C. (1987): "Electrostatic charge on a dust size distribution in a plasma", *J. Geophys. Res.* **92** 12057
- Mendis, D.A. (1979): *Astrophys. Space Sci.* **65** 5
- Mendis, D.A., Houpis, H.L.F., Hill, J.R. (1982): "The gravito-electrodynamics of charged dust in planetary magnetospheres", *J. Geophys. Res.* **87** 3449
- Reasoner, D.L., Lennartsson, W., Chappell, C.R., Rosen, A. (eds) (1976): *Spacecraft Charging by Magnetospheric Plasmas* (Amer. Inst. of Aeronautics and Astronautics, New York). p. 89
- Wollman, E.R. (1988): "A grain plasma model of galaxies", *Laser and Particle Beams* **6** 545

Index

- Absorption
 - by collisions, 266
 - by filaments, 275
- Absorption coefficient, 262, 272, 274, 276, 283
- Accumulation of matter
 - by gravity, 299, 325
 - by ion pumps, 168
 - by Marklund convection, 166
 - in pinches, 28
- Active galaxy nuclei, 239, 248, 251
- Alfvén, H., 23, 30, 44, 64, 171, 198
- Alfvén limiting current, *see* Particle beams
- Alfvén speed, 51, 107, 297
- Alfvén waves, 259
- Ampère's law, 54, 93, 95, 96, 108; *see also*
 - Biot-Savart force
- Aurora
 - auroral curtains, 30
 - auroral kilometric radiation, 37, 190
 - and Birkeland currents, 190
 - diocotron instability, 128
 - electric fields, 145
 - electrojets, 43
 - and ion conics, 190
 - laboratory simulations, 74
 - particle simulations, 89
 - on planets, 21
 - as plasma phenomena, 2
- Bekefi, G., 255, 272, 283
- Bennett, W.H., 28
- Bennett pinch, *see also* Z pinches
 - accumulation of matter, 28
 - in cosmic plasma, 26
 - the cylindrical pinch, 59
 - filamentary structures, 28
 - sheet beams, 74, 190, 248
 - the sheet pinch, 61
 - as sources of synchrotron radiation, 229
- Bennett profile, 110
- Bennett relation, 28, 55, 60, 65
 - generalized, 52
- Biot-Savart force, 111, 119, 236, 243, 248, 297
- Biot-Savart law, 95; *see also* Ampère's law
 - and induction field, 201
- Birdsall, C.K., 287, 298
- Birkeland, K., 43
 - terrella experiment, 44
- Birkeland currents
 - association with inverted V events, 48
 - in astrophysical plasmas, 48, 111
 - as an atmospheric heat source, 47
 - in aurora, 48, 190
 - and the Carlqvist relation, 62
 - at center of Milky Way, 48
 - and the cosmic microwave background, 275
 - and double layers, 70, 183
 - and force-free fields, 29
 - of galactic dimension, 66, 285
 - history of, 43
 - in the intergalactic medium, 66
 - in ionosphere, 23
 - in ionosphere of Venus, 48
 - in Jupiter-Io system, 21
 - in laboratory plasma, 47
 - in quasars, 250
 - in solar prominences, 48
 - from spacecraft injected electron beams, 47
 - in spiral galaxies, 128

- Blackbody radiation, 270, 271, 272
 - cosmic microwave background, 39, 277
 - in electromagnetic spectrum, 37
 - intensity, 273, 276
 - from isotropic plasma, 270
 - Planck formula, 270
 - and plasma filaments, 277, 278
 - Rayleigh-Jeans law, 37, 271, 274
 - Stefan's law, 270
- Boltzmann equation, 49
- Bostick, W.H., 23, 73, 300
- Bremsstrahlung
 - from electrons in vicinity of an atom or ion, 197
- Brewster's angle in anisotropic plasma, 265
- Buneman, O., 30, 286, 294, 296
- Buneman-Hartree criterion, 286
- Bursts
 - in auroral kilometric radiation, 190
 - broadband, from the dense plasma focus, 229
 - broadband, from exploded wires, 229
 - broadband, from vacuum sparks, 229
 - from charged particle orbits, 210
 - gamma ray, from cosmic sources, 251
 - gamma ray, from solar flares, 195
 - of high energy particles, 156
 - microwave, from relativistic electron beams, 229
 - microwave, from solar flares, 194, 229
 - neutron, from dense plasma focus, 23
 - neutron, from solar flares, 195
 - synchrotron radiation, from Jupiter, 283
 - synchrotron radiation, from simulated quasars, 250
 - synchrotron radiation, from Z pinches, 234
 - time duration, 236
 - total power emitted, 234
 - X ray, from cosmic sources, 251
 - X ray, from solar flares, 191
 - X ray, from Z pinches, 118, 232
- Carlqvist relation, 58
 - and Birkeland currents in Earth's magnetosphere, 62
 - and currents in the galactic medium, 66
 - and currents in the interstellar medium, 65
 - and currents in the solar atmosphere, 63
 - and heliospheric currents, 64
- Chandrasekhar, S., 29
- Chapman, S., 43
- Charged particle acceleration, 23
 - in aurora, 149
 - collective ion acceleration, 23, 156
 - in dense plasma focus, 156
 - in double layers, 173
 - electron runaway, 169, 244
 - in field-aligned electric fields, 23
 - in LINACS, 23
 - in magnetic fields, 207
 - radiation from, 198
 - in shocks, 170
 - in wake fields, 23, 79
- Clemmow-Mullaly-Allis diagram, 318
- Collective ion acceleration, *see* Charged particle acceleration
- Collision frequency
 - electron-neutral, 253
 - electron-electron, 168
 - ion-neutral, 253
 - Monte Carlo, 298
 - proton-neutral, 5
 - for 2D simulations, 298
 - for 3D simulations, 298
- Collisions
 - Monte Carlo model, 298
 - and plasma wave absorption, 266
 - simulated, 297
 - and viscosity, 325
- Cosmic microwave background, 37, 277
 - dipole anisotropy, 37
- Cosmic rays, 8, 29, 39, 56, 121, 123, 170, 198
 - from galactic double layers, 195
 - solar, 195
- Coulomb scattering, 168
- Critical ionization velocity, 30
- Crusius-Schlickeiser function, 279
- Currents, *see also* Birkeland currents
 - "doubleness" in interacting currents, 119
 - magnetic interaction between, 94
 - simulation of interacting currents, 110
- Dawson, J., 287
- Debye cube, 287

- Dense plasma focus, 48, 119, 158, 161, 232
and the formation of planets, 156
- Dessler, A.J., 44
- Dielectric tensor, 255, 317
- Diffusion
ambipolar diffusion, 113, 185
magnetic, 51
magnetic diffusion time, 51
- Dipole approximation, 202
- Doppler shift
of plasma oscillations, 70
of synchrotron radiation, 212
- Double layers, 37, 171, 195
in association with Birkeland currents, 70
in association with currents, 183, 186
in auroral circuit, 188, 190
boundary conditions, 183
and the Buneman instability, 180
and cosmic radiation, 195
drifts of, 188
energy sources, 173
exploding, 184, 186
in galaxies, 195
noise and fluctuations, 186
oblique, 188, 190
as a particle accelerator, 173
particle simulations, 180, 182
in quasars, 194
in radio galaxies, 194
relativistic, 175, 176
series of, 185
in solar flares, 191
as surface phenomena, 185
and synchrotron radiation, 195
as a virtual anode, 185
Vlasov simulations, 180
- Double radio galaxies, 125, 240, 248
particle simulations, 243
plasma properties of, 16
and quasars, 248
radiated power, 243
radio properties, 236
synchrotron spectrum, 243
- Dreicer field, 169
- Electrical discharges
associated with lightning, 22, 260
- in aurora, 21
breakdown in atmosphere, 159
burst signatures of, *see* Bursts
in cosmic plasma, 22
in dielectrics, 156
in laboratory, 22
Lichtenstein figures, 156
penumbra formation, 156
on surfaces, 156, 314
on surfaces of giant planets, 156
- Electric dipole moment, 202
- Electric fields
acceleration of charged particles, 23, 285
in aurora, 149, 155
in cosmic plasma, 137, 170
field-aligned, *see* Field-aligned electric fields
in galaxies, 195
generation mechanisms, 138
in ionosphere, 155
in magnetosphere, 146, 154, 155
Marklund-Blomberg model of ionosphere, 153
measurements, 138, 143
motion induced, 103
near-earth, 40
wake fields, 79
in Z pinches, 236
- Electromagnetic forces, 112, 285, 300; *see also* Ampère's law and Biot-Savart force
between charges, 299
as derivatives of coefficients of inductance, 108
polarization forces, 113
between two circular loops, 99, 101
between two infinite conductors, 97
between two parallel filaments, 108
- Electromagnetic spectrum, 33, 253, 285
solar, 191
- Electrostatic shocks, 145, 176
- Elements
abundances, 10, 168
in galaxies, 168
separation of, 43, 165
- Elliptical galaxies
and double radio lobes, 131
formation of, 128

- Elliptical galaxies (*cont.*)
 particle simulation of, 134
 radio properties, 236
- Emission
 stimulated, 272
- Emission coefficient, 267, 274, 280, 282, 283
 for a Maxwellian energy distribution of electrons, 227
 for spontaneous emission, 216
- Emissivity
 for a Maxwellian distribution of electrons, 227
 for ordinary and extraordinary modes, 219
 velocity-averaged emissivity, 222
- Energy
 in magnetic fields, 106
 in plasma motion, 107
 radiated by an accelerated charge, 206
 of relativistic particles, 228
 released in double layers, 183
 released in solar flares, 191, 194
 storage in force-free fields, 107
 storage of magnetic energy, 106
 in system of current loops, 106
 transport in plasma, 254
- Energy conservation equation, 273, 281
- Energy density
 in cosmic plasmas, 23
 equipartition of, 122
 of electromagnetic fields, 254
 in gamma ray background, 34
 in the infrared background, 37
 in laboratory plasmas, 23
 in lightning, 23
 of longitudinal plasma waves, 256
 in the microwave background, 37
 in the radio wave background, 39
 of a transverse electromagnetic wave, 255
 in ultraviolet background, 36
 in the visible background, 37
 in X ray background, 34
- Energy flux
 electromagnetic, 255
 kinetic, 255
 nonelectromagnetic, 255
- Equation of transfer, 267
- Fälthammar, C.-G., 43
- Faraday disk dynamo, 104
- Faraday rotation, 72, 121, 124, 322
- Faraday's law, 102, 104
- Field-aligned currents, *see* Birkeland currents
- Field-aligned electric fields, 23, 143
 collisionless thermoelectric effect, 143
 double layers, 146
 electrostatic shocks, 145
 magnetic mirror effect, 144
 as sources of cosmic rays, 170
- Filaments, *see* Plasma filaments
- Force-free field, 28, 70, 76, 193, 194
- Forces, *see* Electromagnetic forces, Gravitational force, Radiation forces
- Galactic magnetic fields, *see also* Double radio galaxies, Elliptical galaxies, Milky Way Galaxy, Peculiar galaxies, Seyfert galaxies, Spiral galaxies
 Faraday rotation measurements, 121
 optical polarization measurements, 121
 synchrotron radiation measurements, 121
 Zeeman splitting measurements, 121
- Galaxies, *see also* Double radio galaxies, Elliptical galaxies, Milky Way Galaxy, Peculiar galaxies, Seyfert galaxies, Spiral galaxies
 abundances of elements, 168
 cD type, 237
 clusters of galaxies, 16, 66, 135
 Cygnus A, 237, 241, 243, 244, 245
 electric fields in, 195
 Fornax A, 241
 IC 342, 127
 interacting, 16, 248
 M31, 127, 285
 M51, 125
 M82, 198
 M83, 128
 M87, 132, 198, 244
 M101, 128
 Markarian 176, 251
 Markarian 509, 251
 N type, 237
 NGC 253, 128

- NGC 1316, 133, 241, 242
 NGC 1317, 133
 NGC 2998, 128
 NGC 3198, 128
 NGC 3646, 128, 132
 NGC 4151, 128, 130, 250
 NGC 4486, 198
 NGC 4736, 128
 NGC 5033, 128
 NGC 6946, 125
 PKS 1217+02, 251
 plasma densities, 16
 as plasma pinches, 66, 195
 radio luminosity function, 237
 synchrotron radiation, 121, 197
 3C236, 237
 3C273, 250
 Gamma rays, 33
 from cosmic sources, 252
 in electromagnetic spectrum, 34
 gamma ray background, 34
 from solar flares, 14, 191, 194, 195
 Geometrical optics, 262, 270
 Gravitational force, 1, 17, 59, 60, 63, 65, 67,
 285, 286, 299, 300, 325
 Gravitational potential, 30, 50, 300
 Group velocity, 256, 260

 Hartree, D.R., 286, 291
 Heaviside, O., 1
 Heaviside
 Kennelly-Heaviside layer, 253
 operational calculus, 309, 314
 Helmholtz equation, 107
 Herlofson, N., 198
 Hertz, H., 1, 253
 HI regions, 16
 in association with magnetic fields, 127,
 168
 degree of ionization, 17
 magnetic fields in, 121
 Hot spots
 in cosmic jets, 245
 in plasma pinches, 118, 232
 in quasars, 250
 in spiral galaxies, 250

 Inductance, 104
 mutual inductance, 105, 108
 self-inductance, 104
 of solar flares, 193
 Induction field, 199
 Infrared radiation
 in electromagnetic spectrum, 37
 Instabilities
 beam hollowing, 76
 Buneman two-stream, 68, 180, 188
 coronal, 14
 diocotron, 29, 119, 128
 filamentation, 79
 Kelvin-Helmholtz, 29, 287
 kink, 57, 70
 numerical, 289
 sausage, 57, 70
 stabilization by metallic walls, 58
 Intergalactic medium
 magnetic fields, 19, 135
 plasma in, 3, 253
 Interstellar clouds, 48, 59, 65; *see also*
 Nebula
 formation by currents, 66
 Ionosphere, 5, 260, 287, 314

 Jeans condition, 60, 67
 Jeans length
 relation of Debye length, 328
 Jeans mass, 68, 329
 Jets
 in cosmic plasma, 198
 fading, 248
 hot spots in, 245
 in laboratory plasma, 73, 117, 118,
 229
 particle simulations, 248
 and quasars, 244
 as sheet electron beams, 248
 and superluminosity, 244
 synchrotron radiation from, 245
 Jupiter
 electrical discharges on Io, 162
 Jupiter-Io plasma torus, 8, 163
 magnetosphere, 8
 synchrotron radiation, 37, 197, 283

- Kirchoff's circuit laws**, 20
Kirchoff's law, 254, 273
 for anisotropic plasma, 272
- Laboratory astrophysics**, 71
Laboratory simulation of cosmic plasma processes, 71, 118
Langmuir, I., 2, 171
Langmuir condition, 175
Larmor formula, 206
Lienard's formula, 204, 212
Lightning, 260
 natural causes of, 3
 from nuclear explosions, 3
 on planets, 3
 plasma properties of, 2
- Line emission**
 in narrow emission line galaxies, 251
 in quasars, 251
 in Seyfert galaxies, 251
 in spiral galaxies, 128, 251
 in Z pinches, 232
- Liouville's theorem**, 49
Lorentz, H.A., 1
Lorentz equation, 1, 23, 207, 291
Lorentz force, 43, 95, 103, 229
Luce, J., 23
Lundquist parameter, 17, 51
- Magnetic fields**
 from a circular loop, 99
 on Earth, 2
 in galaxies, *see* Galactic magnetic fields
 history of, 93
 from an infinite conductor, 96
 in intergalactic medium, 19, 135
 interplanetary, 15
 isobars from axial currents, 113
 magnetic induction field, 95
 in magnetic variable stars, 15
 measurement in galaxies, 119
 measurement in laboratory plasmas, 108, 110
 measurement in space, *see* Satellite in the Milky Way Galaxy, 19
 in neutron sources, 19
 nonconservative, 102
 quasi-stationary, 101
 random, large-scale approximation, 277
 in stars, 19
 in Z pinches, 236
- Magnetic fields in galaxies**, *see* Galactic magnetic fields
- Magnetic Reynolds number**, 51
Magnetobremstrahlung, *see* Cyclotron radiation
- Magnetohydrodynamics**
 basic equations, 49
 continuity equation, 50
 equation for magnetic induction, 51
 equation for mass conservation, 50
 momentum equation, 50
 single fluid force equation, 50, 325
- Magnetosphere**
 bow shock, 7
 cometary, 8
 Earth's, 5
 on Jupiter, 163
 magnetopause, 7
 planetary, 8, 285
 plasmasphere, 7, 261
 polar horns, 7
 transmission line properties, 21, 314
- Marconi, G.**, 253
Marklund convection, 165
Maxwell, J.C., 1, 253
Maxwell-Hertz-Heaviside equations, 1, 49, 137, 254, 288, 291, 302, 317
Maxwell's equations, *see* Maxwell-Hertz-Heaviside equations
- Microwaves**
 from beam instabilities, 86
 cosmic microwave background, 37
 in electromagnetic spectrum, 37
 from galactic MASERS, 37
 in klystrons, 37
 in magnetrons, 30, 37, 188, 286, 291
 from particle beams, 22, 37
 in relativistic klystrons, 70
 in slow wave structures, 37
 from solar flares, 14
 from virtual cathodes, 37
 from Z pinches, 229

- Milky Way Galaxy, 16, 37, 170, 237
 double radio emission at center, 240
 inflow of neutral hydrogen, 168
 magnetic fields, 121, 122, 123, 127
 plasma filaments, 48, 124
 Sagittarius arm, 124
 synchrotron radiation between spiral arms, 123
 synchrotron radio emission, 123
- Nebula
 Crab, synchrotron radiation from, 198
 Lagoon, 48
 Orion, 48
 Veil, 18, 48
- Neutral hydrogen in cosmic plasma, *see* HI regions
- Neutrons
 from D–D reactions, 23
 from dense plasma focus, 156
 from solar flares, 14
- Newton's third law, 95
- Optical depth, 268
 in plasma filaments, 276
- Parseval's theorem, 207
- Particle beams
 Alfvén limiting current, 55, 78
 Budker's parameter, 56
 charge neutralized beam propagation, 56, 77, 87
 cross-field beam parameter, 30
 current neutralized beam propagation, 57, 77
 diocotron instability, 30
 in double layers, 173
 filamentation, 79
 Lawson's interpretation, 56
 propagation along a magnetic field, 58
 relativistic, 37, 60, 78
 Schönherr whirl stabilization, 58
 simulations, 76
 space charge limiting current, 37, 56, 285
- Particle simulations, 285
 of the aurora, 89, 191
 benchmarking, 76
 of Birkeland currents, 76
 of cosmic jets, 248
 Courant condition, 295
 cycloid fitting, 295
 definition of dimensionality, 288
 of double layers, 180
 of double radio galaxies, 243
 of elliptical galaxies, 134
 gravitational, 296
 Green radiation condition, 296
 history of, 286, 287
 ISIS, 77
 Lindman radiation condition, 296
 of magnetic fields in galaxies, 128
 of particle beams, 76
 of quasars, 250
 and relativity, 296
 spectral methods 287
 of spiral galaxies, 126
 SPLASH, 81, 111
 superparticles, 297
 time scale compression, 297
 TRISTAN, 111, 301
 of Z pinches, 233, 236
- Permeability, 1
- Permittivity, 1
- Planck law, 268, 270, 271
- Plasma
 approximation, 50, 69
 associated with Sun, 10
 cellular, 2, 185, 186
 in comets, 8
 as compared to liquids, solids, and gases, 2
 conductivity, 2, 51, 137, 305
 definition of, 1
 in double radio galaxies, 16
 dusty, 325, 326
 on Earth, 2
 in exploded foils, 72
 in exploded wires, 2, 72, 117
 filamentary, *see* Plasma filaments
 in galaxies, 16
 grain, 176, 325, 329
 in HI regions, *see* HI regions
 interstellar, 15

Plasma (*cont.*)

- laboratory jets, 73
- lifetimes, 2
- nonneutral, 2
- from nuclear sources, 3
- positron, 2
- in solar system, 8
- as sources of electromagnetic radiation, 2
- in stars, 15, 73
- Plasma filaments, 2, 23, 28, 48, 76, 87, 106, 108, 111, 112, 113, 137, 159, 183, 228, 229, 253, 275, 276
 - galactic, 16, 48, 124, 127, 186, 243, 278
 - in heliospheric current system, 64
 - on Io, 162
 - prominences, 14
- Plasma guns, 73, 156, 158
- Plasma waves, 17, 70, 253, 259, 262, 265, 317
- Plasmoids, 70, 73
- Plyutto, A.A., 23
- Poisson's equation, 67, 69, 70, 174, 178, 286, 292, 302
- Poisson-Vlasov equations, 145, 176
- Polarization, *see* Radiation, Radio waves, Synchrotron radiation
- Potemra, T., 44
- Power
 - emission from galaxies, 236
 - emitted by an accelerated electron, 211, 218
 - emitted by volcanic plumes on Io, 163
 - in spectral range, 263, 278
 - total power from a Maxwellian distribution of electrons, 228
- Power density
 - in galaxies, 236
 - from radiating plasma filaments, 228
- Poynting's vector, 201, 254, 255
- Propagation
 - constant, 309
 - of electromagnetic radiation, 253, 256
 - function, 311
- Quasars
 - and jets, 244
 - particle simulations of, 250
 - radio properties, 236
 - relation to radio galaxies, 248, 251

- spectra, 250
- synchrotron radiation, 197

Radiation, 16, 127; *see also* Blackbody radiation, Bremsstrahlung, Synchrotron radiation

- from an accelerated charge, 198
- from an accelerated electron in a magnetic field, 207
- auroral, 37
- bound-bound electron transitions, 197
- cyclotron, 274, 277
- from dipole elements, 204
- electromagnetic, theory of, 253
- enhancement by multiple filaments, 118, 229, 234
- free-bound electron transitions, 197
- free-free electron transitions, 121, 197
- from neutral hydrogen, 16, 127
- from plasma oscillations, 197
- from plasma recombination, 197
- planetary, 37
- plasma thermal emission, 230
- polarization, 207, 317
- X ray, *see* X rays
- Radiation fields, 201, 236
- Radiation forces, 325
- Radiation zone, 211
- Radio luminosity function, 237
- Radiotelescopes
 - Effelsberg, 124, 126
 - Green Bank, West Virginia, 38
 - Hobart, Tasmania, 39
 - Jodrell Bank, 245
 - RATAN-600, Zelenchukskaya, USSR, 38
 - Testa Grigia, Italy, 38
 - VLA, 124, 245, 246
- Radio waves
 - and the discovery of the ionosphere, 5, 283
 - in electromagnetic spectrum, 37, 285
 - polarization, 126, 219, 317
 - solar sporadic emissions, 197
 - from synchrotron radiation, 197
- Razin-Lorentz factor, 281
- Reber, G., 39, 240
- Reciprocity theorem, 105
- Refractive index, 253, 264, 283, 318

- Rostocker, N., 58
 Rotation measure, 121
- Satellite
 GEOS, 140
 ISEE, 140, 149
 S3, 146, 149
 TRIAD, 44
 Viking, 146, 149
- Saturn
 magnetosphere, 8
 plasma torus, 8
 synchrotron radiation, 37
- Scaling laws, 300
- Schroedinger's equation, 286
- Schwinger, J., 217
- Seyfert galaxies
 Markarian 509, 251
 NGC 4151, 250
 radio properties, 236, 239
 and relation to quasars, 250
 spectra, 250
- Skin depth
 electromagnetic, 306
 plasma, 77
- Snell's law, 264, 266
- Solar atmosphere
 currents in, 63, 191
- Solar flares, 14, 191, 193, 198
 and double layers, 191
 two ribbon flares, 191
- Solar system
 plasma transition regions, 10
- Solar wind, 6, 41
- Solitons, 176
- Source function, 268, 272, 275
- Spectral energy density, 207
- Spectral flux, 262
- Spectral intensity, 263, 275
- Spectrum, *see* Electromagnetic spectrum
- Spiral galaxies, 126
 bisymmetric magnetic fields, 126, 128
 diocotron instability, 128
 emission lines, 128
 hydrogen deficient cores, 128
 magnetic fields, 126, 128
 magnetic fields and neutral hydrogen, 127
 plasma filaments, 127
 radio properties, 236
 rotation velocities, 128
 spectra, 250
- Stars, 1, 2, 6, 15, 19, 36, 37, 73, 121, 122,
 133, 285, 299, 325
- Störmer, C., 286
- Sun
 chromosphere, 10, 107, 191
 corona, 10, 107, 191
 heliosphere, 14
 photosphere, 10, 107
 sunspots, 12, 191
- Supernovae
 anisotropy of charged particle fluxes,
 170
 synchrotron radiation, 197
- Synchrotron radiation, 197, 251
 angular distribution, 211, 236
 beam energy, 197
 continuous spectra, 197
 from cosmic sources, 236, 252
 critical frequency, 218, 243
 Crusius-Schlickeiser function, 279
 from an ensemble of electrons, 222
 frequency distribution, 213
 gain, 213
 from galaxies, 197
 in galaxies, 121
 and gamma ray astronomy, 198
 PHERMEX experiment, 229
 and plasma effects, 279
 polarization of, 197, 219
 pulsed, 210
 radiation lobes, 236
 in solar flares, 198
 spectral lines, 216
 from Sun, 197
 from supernovae, 197
 and X ray astronomy, 198
 from Z_p pinches, 229, 236
- Temperature
 of charged particle beams, 12, 79, 297
 of dusty clouds, 326
 equilibrium, 268
 of interstellar grains, 121, 327

- Temperature (*cont.*)
 of plasma, 1
 radiation, 273, 274
 of solar layers, 12
- Time-domain reflectometry, 314
- Transmission lines
 characteristic impedance, 312
 on Earth, 20
 equations, 313
 ionosphere-magnetosphere, 21
 magnetically insulated, 21
 in space, 20, 186, 305, 315
 telegrapher's equation, 308
- Trubnikov, B.A., 274, 276
- Ultraviolet radiation
 in electromagnetic spectrum, 36
 from solar flares, 191
- Universe
 currents in, 48
 high-energy-plasma universe, 34
 intrinsic impedance, 199
 visual, 33
- Van Allen belts, 3
- Vector potential, 99
- Visible light, in electromagnetic spectrum,
 37
- Vlasov equation, 176
- Vortices, 29, 30, 33, 48, 74, 84, 86, 89, 181,
 182
- Wake fields, *see* Charged particle acceleration
- Webster, H., 74
- Wernholm, O., 23
- Whistlers, 154, 260, 261, 318
- X radiography, 71
- X ray background, 34
- X rays
 from cosmic sources, 252
 from dense plasma focus, 48, 229
 detectors, 73, 232
 in electromagnetic spectrum, 33
 from exploded wires, 232
 from particle beams, 22
 solar, 12
 from solar flares, 191, 194
 from synchrotron radiation, 198
 from Z pinches, 229, 230, 233
- X ray spectroscopy, 229, 230
- Z pinches, 72, 117, 156
 interacting, 110, 116, 118, 229, 236, 242,
 250
 as sources of synchrotron radiation, 229
 velocities of, 117, 118

In the past decade, our understanding of plasma physics has expanded greatly and has contributed extensively to current research in astrophysics. The explosive growth in plasma physics has been concentrated mainly in two research areas: work directed toward controlled nuclear fusion, and work in space physics. This book addresses the growing need to apply these complementary discoveries to astrophysics.

Today many scientists recognize plasma as the key element to understanding the generation of magnetic fields in planets, stars, and galaxies; the behavior of stellar atmospheres and the interstellar medium; the acceleration and transport of cosmic rays; and many other phenomena occurring in radio galaxies, galactic nuclei, quasars, and so forth.

These phenomena have only recently been recognized as a unified discipline. The material in *Physics of the Plasma Universe* addresses the known properties of matter in the plasma state and addresses topics in contemporary astrophysics such as magnetism in plasma; electric fields in space plasmas; double layers, synchrotron radiation, and energy transport in plasmas; and particle-in-cell simulation of astrophysical plasmas. Examples of specific problems are included, as well as numerous useful illustrations and appendixes that discuss transmission line concepts in space plasmas, the polarization properties of plasma waves, and dusty and grain plasmas.

ISBN 0-387-97575-6
ISBN 3-540-97575-6