Magnetohydrodynamics and Turbulence

Alexander Schekochihin, Part III (CASM) Michaelmas Term 2005

SUGGESTED READING

I aim to give you a coherent set of lectures that would be self-contained. The reading suggestions below are not obligatory, they are given simply so that you know where to look for an alternative (and in many cases much more extensive) account of the material discussed in class. As we move along, I will give you more references to articles, reviews etc. These, as well as specific reading suggestions for individual lectures will be posted in the Course Blog: see `http://www.damtp.cam.ac.uk/user/as629/course_blog.html`.

I. Turbulence

1. L. D. Landau & E. M. Lifshitz, *Fluid Mechanics* (Butterworth-Heinemann 1995)
   — A lucid account of Kolmogorov's theory is given in §§33-34.

2. U. Frisch, *Turbulence. The Legacy of A. N. Kolmogorov* (CUP 1995)
   — A book that is now a standard reference. It presents Kolmogorov's theory very thoroughly (if in a somewhat formalistic way). Also contains a long chapter reviewing the literature and the modern (as of 1995) state of the subject.

3. P. A. Davidson, *Turbulence — An Introduction for Scientists and Engineers* (OUP 2004)
   — A compendium of knowledge on turbulence. Everything you ever wanted to know about it but were afraid to ask. Very well written.

4. G. K. Batchelor, *The Theory of Homogeneous Turbulence* (CUP 1982)
   — A classic essay on turbulence.

5. A. S. Monin & A. M. Yaglom, *Statistical Fluid Mechanics: Mechanics of Turbulence,* 2 vols. (MIT Press 1979) — The Russian turbulence bible by two of Kolmogorov's disciples. Out of print.

6. S. B. Pope, *Turbulent Flows* (CUP 2000)
   — An engineering-style monograph.

7. W. D. McComb, *The Physics of Fluid Turbulence* (Clarendon 1992)
   — A good monograph on closure schemes, if you must know about them.

II. Magnetohydrodynamics

1. R. M. Kulsrud, *Plasma Physics for Astrophysics* (Princeton University Press 2005)
   — A new book by a renowned plasma astrophysicist. I learned MHD from his lectures, so I expect you may find some similarities between my presentation and his.

2. P. A. Sturrock, *Plasma Physics* (CUP 1994)
   — A (mostly) sensible introduction to plasma physics. MHD is covered in Chapters 11-17.

3. J. P. Goedbloed & S. Poedts, *Principles of Magnetohydrodynamics* (CUP 2004)
   — A brand new and very thorough and meticulous presentation of the subject. Also written by plasma physicists with applications to astrophysics and to fusion devices in mind.

4. P. A. Davidson, *An Introduction to Magnetohydrodynamics* (CUP 2001)
   — A very good text written from a non-plasma perspective. A lot of fun to read. The second half of the book is an extensive introduction to engineering/metallurgical applications.

5. T. G. Cowling, *Magnetohydrodynamics* (Adam Hilger Ltd 1976)
   — An out-of-print classic. A very slim and very good book.

Here are a few books for further reading on MHD and plasma physics (these go well beyond the course material).

1. S. Chandrasekhar, *Hydrodynamic and Hydromagnetic Stability* (Dover 1981)
   — The bible of MHD instabilities.
2. H. K. Moffatt, *Magnetic Field Generation in Electrically Conducting Fluids* (CUP 1978)
   — A classic account of the mean-field dynamo theory. Out of print.
3. E. N. Parker, *Cosmical Magnetic Fields: Their Origin and Activity* (Clarendon 1979)
   — A monograph by one of the founders of the subject. Out of print.
4. D. Biskamp, *Nonlinear Magnetohydrodynamics* (CUP 1997)
   — An oft-cited monograph by one of the gurus of the numerical simulations of MHD.
5. L. Spitzer, *Physics of Fully Ionized Gases* (Wiley 1962)
   — A classic of plasma physics by the founder of the US fusion program.
6. *Basic Plasma Physics,* A. A. Galeev & R. N. Sudan (eds.), 2 vols. (North-Holland 1983, 1984)
   — The bible of laboratory plasma physics. Review articles by the leading scientists. Quality varies, but the book as a whole is a good resource.
7. A. F. Alexandrov, L. S. Bogdankevich & A. A. Rukhadze, *Principles of Plasma Electrodynamics* (Springer 1984) — An excellent systematic treatment of plasma physics. Out of print.

III. MHD Turbulence

We do not know very much about MHD turbulence. Close examination shows that we know even less than we think we do. Consequently there is no standard textbook account of the subject. Here are some books that more or less pertain to what I will talk about.

1. D. Biskamp, *Magnetohydrodynamic Turbulence* (CUP 2003)
   — A review of (the author's understanding of) the present state of the subject.
2. V. E. Zakharov, V. S. Lvov & G. Falkovich, *Kolmogorov Spectra of Turbulence: Wave Turbulence* (Springer 1992) — A very good monograph on weak turbulence theory. It does not include the Alfvén-wave problem but provides solid mathematical exposition of the weak-turbulence approach. Out of print.
3. S. Childress & A. Gilbert, *Stretch, Twist, Fold: The Fast Dynamo* (Springer 1995)
   — A standard monograph on fast dynamos. Out of print.
4. Ya. B. Zeldovich, A. A. Ruzmaikin & D. D. Sokoloff, *The Almighty Chance* (World Scientific 1990)
   — A somewhat loosely assembled book, which, nevertheless, is worth reading for the wealth of physical insights it contains. It is a book on the physics of randomness rather than exclusively on MHD turbulence. Small-scale dynamo is treated in Chapter 9.
5. N. G. van Kampen, *Stochastic Processes in Physics and Chemistry* (Elsevier 1992)
   — A book on stochastic methods, not on MHD. However, these are very useful things to know for someone interested in the subject. A very thorough and systematic treatment. This is for further reading, not for the course material.

There are also sections on MHD turbulence in both P. A. Davidson's books listed above.

If you wish to investigate the origins of my views on MHD turbulence, see links to my papers on `http://www.damtp.cam.ac.uk/user/as629/publist.html`.