# PHY 7097: Molecular Magnetims Spring 2015 Professor Mark W. Meisel

**“*in vivo*”** schedule (**black text: projected and tentative**; **purple text: past**; **blue text: hotlinks**;

**red text important announcements**; **green text: fixed final exam**)

**Note:** Schedule is “projection” and revisions will be announced in class and subsequently posted online.

Week 1 Jan 07 Class Starts, Introduction to the Course

[**Molecular Magnetism Web**](http://www.molmag.de/) thanks to [Jürgen Schnack](http://obelix.physik.uni-bielefeld.de/~schnack/)

**Molecule-based Magnets – An Overview**, J.S. Miller and A.J. Epstein,

*MRS Bulletin* 25 (2000) 21-30 <http://dx.doi.org/10.1557/mrs2000.221>

Jargon and Perspective: Green Tree Snake

[**Family Tree of Magnetism**](https://www.tcd.ie/Physics/Magnetism/Guide/Magnetism/t2.jpg), C.M. Hurd, *Contemp. Phys.* 23 (1982) 469-493.

Jan 09 Discuss HW of setting schedule.

The issue of length scales: one example of what Meisel is pondering

Blather-meter installed…

<http://iopscience.iop.org/1367-2630/9/7/222/>

Week 2 Jan 12 Sakai “Resources” for PHY7097 posted, you should have received email

C.P. Landee, M.M. Turnbull, “Review: A gentle introduction to magnetism:

units, fields, theory, and experiment”, [J. Coord. Chem. 67 (2014) 375-439](http://www.tandfonline.com/doi/abs/10.1080/00958972.2014.889294?journalCode=gcoo20#preview).

Discussion of Primary, Secondary, Tertiary topics that you want covered.

Jan 14 Continue story of “one road to discovery” see Lecture 2 (2015-01-09)

Review “Homework” of LRO (long-range order) in spatial-spin dimensions

Jan 16 Detailed Discussion of LRO “table” and Recap “length” issues

Week 3 Jan 19 No class, King Holiday.

Jan 21 Almost Finish story of “one road to discovery” see Lecture 2 (2015-01-09)

Jan 23 Interactive Day in Small Group Projects

Week 4 Jan 26 Finish story of “one road to discovery” see Lecture 2 (2015-01-09)

Start with Magnetometry and SQUIDs as amplifiers

Reminder: 1-on-1 Office Hour (or by appointment) meeting with Meisel

Jan 28 Continue with SQUIDs

Jan 30 Interactive Day in Small Groups

Week 5 Feb 02 Brief review of Interactive Progress, some “permutations”

Group driven reports? When? (Decided on Monday, Feb 04)

SQUIDs: dc and rf with references, see posted slides.

dc SQUID covered.

Feb 04 rf SQUID covered.

Feb 06 Interactive Day in Small Groups

Week 6 Feb 09 Group updates with 1 or 2 Powerpoint slides

Feb 11 Group udpdate continued, EasySpin comments

Feb 13 Interactive Day in Small Groups

Week 7 Feb 16 Finish Small Group Updates and Recap/Discuss

Start Multiferroics Material:

[The European School on Magnetism](http://magnetism.eu/esm/)

[Magnetoelectric Multiferroics: by Kathrin Dörr (2007)](http://magnetism.eu/esm/2007-cluj/slides/doerr1-slides.pdf)

Aside on Units, see:

[An introduction to magnetism in three parts by Wulf Wulfhekel](http://magnetism.eu/esm/2013/slides/wulfhekel-slides.pdf)

Feb 18 SQUID queue reviewed, Multiferroics continued by review Dörr (2007)

Feb 20 **Aside on Issues:**

**(1)** Corrections for diamagnetic “supporting stuff”?

Pascal’s Constants: see “Diamagnetic Corrections and Pascal's Constants”,

G.A. Bain and J.F. Berry, *J. Chem. Educ.*, 2008, 85 (4), 532-536,

[DOI: 10.1021/ed085p532](http://pubs.acs.org/doi/pdf/10.1021/ed085p532)

**(2)** χ × *T* at Room Temperature not “spin only” value?

Then spin-orbit interactions persist to 300 K? Try, for example:

“Magnetic functions beyond the spin-Hamiltonian”,

volume editor: D.M.P. Mingos ; with a contribution by R. Boča.

Published: Berlin ; New York : Springer, 2006. [UF Library E-book](http://uf.catalog.fcla.edu/uf.jsp?ix=ti&st=Magnetic%20Functions%20Beyond%20the%20Spin-Hamiltonian)

Full citation: Bocǎ , R. In *Magnetic Functions Beyond the Spin-Hamiltonian*;

Mingos, D. M. P., Ed.; Springer-Verlag: Berlin, 2006; Vol. 117, pp 1− 264.

**Multiferroics continued:** HW contributions? MWM goes first.

**d0/dn issue?**

“Recent progress in first-principles studies of magnetoelectric multiferroics”,

C. Ederer and N.A. Spaldin,

*Current Opinion in Solid State and Materials Science*, 9 (2005) 128-139,

[doi:10.1016/j.cossms.2006.03.001](http://www.sciencedirect.com/science/article/pii/S1359028606000192)

“Classifying multiferroics: Mechanisms and effects”, D. Khomskii,

*Physics* 2 (2009) 20, [doi:10.1103/Physics.2.20](https://physics.aps.org/articles/pdf/10.1103/Physics.2.20)

“Noncentrosymmetric Oxides”, P.S. Halasyamani and K.R. Poeppelmeier,

Chem. Mater. 1998, 10, 2753-2769, [doi: 10.1021/cm980140w](https://pubweb.bnl.gov/~frenkel/BTO/ref1.pdf)

**Why?** *Interest in photocontrolled multiferroic behavior?*

**One “New” Development:**

“Tilt engineering of spontaneous polarization and magnetization

above 300 K in a bulk layered perovskite”, M.J. Pitcher, P. Mandal,

M.S. Dyer, J. Alaria, P. Borisov, H. Niu, J.B. Claridge, M.J. Rosseinsky,

*Science* 347 (2015) 420-424, [doi:10.1126/science.1262118](http://www.sciencemag.org/content/347/6220/420.abstract?sid=bf627506-1e2b-4cbb-a63a-2ce4943791da)

Week 8 Feb 23 Multiferroics continued?

All the tools on a quasi-1D system:

“Magnetic order and low-energy excitations in the quasi-one-dimensional antiferromagnet

CuSe2O5 with staggered fields”, *Phys. Rev. B* 87, 104413 (2013)

M. Herak, A. Zorko, M. Pregelj, O. Zaharko, G. Posnjak, Z. Jagličić, A. Potočnik, H. Luetkens,

J. van Tol, A. Ozarowski, H. Berger, and D. Arčon,

<http://journals.aps.org/prb/abstract/10.1103/PhysRevB.87.104413>

Feb 25 Continue discussion from previous session.

Feb 27 Informal Session.

Week 9 Mar 02,04,06 No classes, Spring Break

Week 10 Mar 09 Recap where we are and where we are going.

Course requirements:

One “project”, pre-approved by instructor, and classroom presentation (20 min). “Intellectual Merit” (40%)

One outreach “spot” (the elevator speech) or “K-8 activity”. “Broader Impacts” (40%)

A one-pager about where you started and where you finished the wild ride. (20%)

HW: email me about status of Project 1 and need for Project 2.

Update: Physics (MWM) interpretation versus Chemistry interpretation.

An example of different interpretations: S = 1 “chains”.

Mar 11 Antiferromagnetic Spin Modes in CuSe2O5.

“Spin Dynamics in an Antiferromagnet”, Marc Philipp Ross, Diploma thesis (2013) TU-München ([PDF](http://www.wmi.badw.de/publications/theses/Ross,Marc_Diplomarbeit_2013.pdf)).

Mar 13 Finish discussion of Mar 11.

Week 11 Mar 16 SMM discussion begins (with goal of understanding the role of substrates).

[Introduction to Molecular Magnetism (Joris van Slageren, Universität Stuttgart)](http://obelix.physik.uni-bielefeld.de/~schnack/molmag/material/123.pdf)

[Elementary Magnetic Excitations in AntiferromagneticMolecular Nanomagnets (Dr. Waldmann, University of Bern)](http://obelix.physik.uni-bielefeld.de/~schnack/molmag/material/Lecture-APS-2006-Waldmann.pdf)

Mar 18 SMM discussion, AC magnetic response, and surfaces.

Mar 20 Work in mini-groups for projects.

Week 12 Mar 23 Informal discussion with

[Professor Jamie L. Manson](http://www.ewu.edu/cstem/programs/chemistry/chemistry-faculty/jamie-manson), Department of Chemistry and Biochemistry

Eastern Washington University, Cheney, WA

Mar 25 SMM discussion evolves to SCO discussion.

**1.** “Single Molecule Magnets on metallic and magnetic surfaces”, M. Mannini, et al. (R. Sessoli)

<http://www.esrf.eu/files/live/sites/www/files/events/conferences/usersmeeting2011/Abstract_Sessoli_esrf_2011.pdf>

**2.** “Single-molecule Magnet Mn12 on graphene”, X.-G. Li, J.N. Fry, and H.-P. Cheng, PRB 90 (2014) 125447

<http://journals.aps.org/prb/pdf/10.1103/PhysRevB.90.125447>

**3.** “Photomagnetism of iron(II) spin crossover complexes – the *T*(LIESST) approach”, J.-F. Létard, J. Mater. Chem. 16 (2006) 2550-2559, <http://pubs.rsc.org/en/content/articlepdf/2006/jm/b603473j>

**4.** “The spin state of a molecular adsorbate driven by the ferroelectric substrate polarization”, X. Zhang et al. (P.A. Dowben), Chem Commun. 50 (2014) 2255-2257, <http://pubs.rsc.org/en/content/articlepdf/2014/cc/c3cc46892e?page=search>

Review aspects of professional behavior and expectations.

Mar 27 Work in mini-groups for projects.

Week 13 Mar 30 Continue SCO discussion and influence of solid support.

Papers discussed:

Referenced in [1] on March 25:

“X-Ray Detected Magnetic Hysteresis of Thermally Evaporated Terbium Double-Decker Oriented Films”,

L. Margheriti, D. Chiappe, M. Mannini, P.-E. Car, P. Sainctavit, M.-A. Arrio, F. Buatier de Mongeot, J.C. Cezar,

F.M. Piras, A. Magnani, E. Otero, A. Caneschi, R. Sessoli, Adv. Mater. 22 (2010) 5488-5493,

<http://onlinelibrary.wiley.com/doi/10.1002/adma.201003275/abstract>

“Quantum tunnelling of the magnetization in a monolayer of oriented single-molecule magnets”,

M. Mannini, F. Pineider, C. Danieli, F. Totti, L. Sorace, Ph. Sainctavit, M.-A. Arrio, E. Otero, L. Joly,

J.C. Cezar, A. Cornia, R. Sessoli, Nature 468 (2010) 417-421,

<http://www.nature.com/nature/journal/v468/n7322/full/nature09478.html>

The above two lead to thinking about:

“Persistent optically induced magnetism in oxygen-deficient strontium titanate”, W.D. Rice, P. Ambwani,

M. Bombeck, J.D. Thompson, G. Haugstad, C. Leighton, S.A. Crooker, Nature Mater. 13 (2014) 481-487,

<http://www.nature.com/nmat/journal/v13/n5/full/nmat3914.html>

“Revealing optically induced magnetization in SrTiO3 using optically coupled SQUID magnetometry and magnetic circular dichroism”, W.D. Rice, P. Ambwani, J.D. Thompson, C. Leighton, S.A. Crooker, J. Vac. Sci. Tech. B 32 (2014) 04E102, <http://scitation.aip.org/content/avs/journal/jvstb/32/4/10.1116/1.4871691>

Apr 01 Continue SCO discussion and influence of solid support.

Papers discussed:

“Modification of Molecular Spin Crossover in Ultrathin Films”, A. Pronschinske, Y. Chen, G.F. Lewis,

D.A. Shultz, A. Calzolari, M.B. Nardelli, D.B. Dougherty, Nano Lett. 13 (2013) 1429-1434,

<http://pubs.acs.org/doi/abs/10.1021/nl304304e>

“Lattice dynamics in spin-crossover nanoparticles through nuclear inelastic scattering”, G. Félix,

M. Mikolasek, H. Peng, W. Nicolazzi, G. Molnár, A.I. Chumakov, L. Salmon, A. Bousseksou, Phys. Rev. B 91 (2015) 024422, <http://journals.aps.org/prb/abstract/10.1103/PhysRevB.91.024422>

Apr 03 As a part of Wednesday’s discussion, Marcus Peprah recommends

“The Spin Crossover Phenomenon Under High Magnetic Field”, A. Bousseksou, F. Varret, M. Goiran,

K. Boukheddaden, J. P. Tuchagues, in *Spin Crossover in Transition Metal Compounds III*,

Topics in Current Chemistry 235 (2004) 65-84, <http://link.springer.com/chapter/10.1007%2Fb95422>

Chiral Magnets? Let’s try a Google search and find at the top of the list

<http://www.thp.uni-koeln.de/natter/research_data/chiral_magnets_website.pdf>

“The fruitful introduction of chirality and control of absolute configurations in molecular magnets”,

C. Train, M. Gruselle, M. Verdaguer, Chem. Soc. Rev. 40 (2011) 3297-3312,

<http://pubs.rsc.org/en/Content/ArticleLanding/2011/CS/c1cs15012j#!divAbstract>

Week 14 Apr 06 Chiral Magnets continued.

Summary of “Molecular Magnetism” and “missed topics”

“Pressure dependence of the exchange anisotropy in an organic ferromagnet”, K. Thirunavukkuarasu,

S.M. Winter, C.C. Beedle, A.E. Kovalev, R.T. Oakley, S. Hill, Phys. Rev. B 91 (2015) 014412,

<http://journals.aps.org/prb/abstract/10.1103/PhysRevB.91.014412>

“Magnetic Anisotropy in a Heavy Atom Radical Ferromagnet”, S.M. Winter, S. Datta, S. Hill, R.T. Oakley,

J. Am. Chem. Soc. 133 (2011) 8126–8129, <http://pubs.acs.org/doi/abs/10.1021/ja202156u>

“Ferromagnetic Ordering in Bisthiaselenazolyl Radicals: Variations on a Tetragonal Theme”, C.M. Robertson,

A.A. Leitch, K. Cvrkalj, D.J.T. Myles, R.W. Reed, P.A. Dube, R.T. Oakley, J. Am. Chem. Soc. 130 (2008)

14791–14801, <http://pubs.acs.org/doi/abs/10.1021/ja8054436>

“Raising efficiency of organic solar cells with electrotropic additives”, S. Karak, Z.A. Page, J.S. Tinkham,

P.M. Lahti, T. Emrick, V.V. Duzhko, Appl. Phys. Lett. 106 (2015) 103303, <http://scitation.aip.org/content/aip/journal/apl/106/10/10.1063/1.4914847>

Apr 08 Small group meetings with/without instructor.

Apr 10 Small group meetings with/without instructor.

Week 15 Apr 13 C and P.

(Apr 14) outreach activity: 3 sessions with 1st graders 8:15 to 9:45, Archer

Leave NPB 07:15 hrs AS,DE,SL

Apr 15 S and D.

Apr 17 M and A.

Week 16 Apr 20 S and X.

Apr 22 J and Last Class.

Final Exam Group 30C: no Final Exam but all graded work completed by Thursday, 30 April, 14:30 hrs.