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Thermodynamics and phase transitions in magnetic materials

Lecture 1

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Overview of Lecture 1

This lecture is an introduction to the physics of phase transitions, including some of the most relevant terminology.

Much of the content will be written on the blackboard.

Why am I interested in magnetic phase transitions?

- Fundamental to our understanding of magnetic order
- The most sensitive parameter (arguably) in a magnetic material – a good barometer of disorder, etc.
- Potential uses
  - Magnetic cooling
  - Power generation from waste heat
  - Magnetic shape memory
  - Self-controlled magnetic hyperthermia

A brief history of the Curie point: Gilbert's *de Magnete*

Gilbert (1544-1603) observed that iron could acquire magnetic properties as a result of being heat-worked by a blacksmith:

"For as when a babe is brought forth into the light from its mother's womb, and acquires respiration and certain animal activities.... so that piece of iron ... while it is returning also from its heated condition to its former temperature, it is imbued with a certain verticity in accord with its position."

The observation of a critical temperature for ferromagnetism - later called a Curie temperature

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Critical exponents: experiment vs theory for *d*=3

Transition type	Material	α	β	γ	ν
		$C \sim \lvert t\rvert^{-\alpha}$	$\langle m\rangle \sim \lvert t\rvert^{\beta}$	$\chi \sim \lvert t\rvert^{-\gamma}$	$\xi \sim \lvert t\rvert^{-\nu}$
Ferromag. $(n=3)$	Fe, Ni	-0.1	0.34	1.4	0.7
Superfluid $(n=2)$	He^4	0	0.3	1.3	0.7
Liquid-gas $(n=1)$	CO_2, Xe	0.11	0.32	1.24	0.63
Superconductors		0	1/2	1	1/2
Mean-field		0	1/2	1	1/2

Here "*t*" is proportional to T-T_c

Table from Ben Simons' lectures on Phase Transitions and Collective Phenomena, U. Cambridge.

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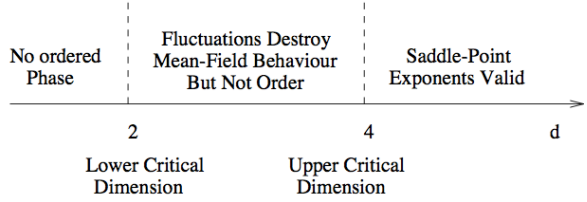
A phase diagram of the Ginzburg-Landau Hamiltonian



This diagram is from Ben Simons' lectures on Phase Transitions and Collective Phenomena, U. Cambridge.