Queen Mary, University of London
School of Physics and Astronomy

Structure and Properties of Functional Materials

Homework Set Ω

Optional hand in (directly to me) by the revision lecture. If you hand in these problems and score highly on them I'll replace your lowest homework score with the score from this set.

Problem 1: Terms and definitions (8 marks)

Explain the following terms or concepts, giving an example of their significance in condensed matter physics:

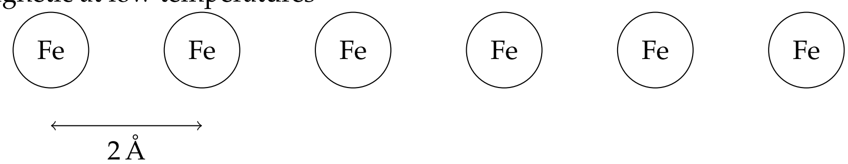
(a) Néel temperature (4)

(b) Weiss mean-field model (4)

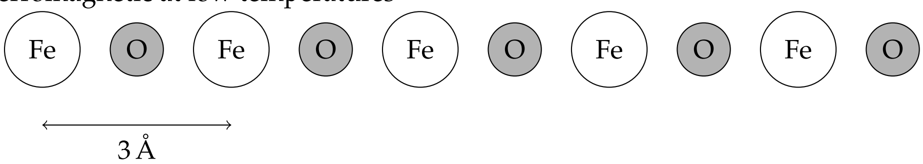
Problem 2: Magnetic diffraction peaks (17 marks)

(a) Each of the following diagrams shows the positions of magnetic atoms in a hypothetical 1D crystal. In each case, calculate the real and reciprocal lattice parameters in two cases: (1) in the high-temperature paramagnetic phase (*i.e.*, if there is no magnetic ordering), and (2) in the low-temperature magnetic phase indicated. If any extra magnetic peaks are expected in the neutron diffraction pattern at low temperature, give the scattering vector Q at which the lowest such peak is expected. (9)

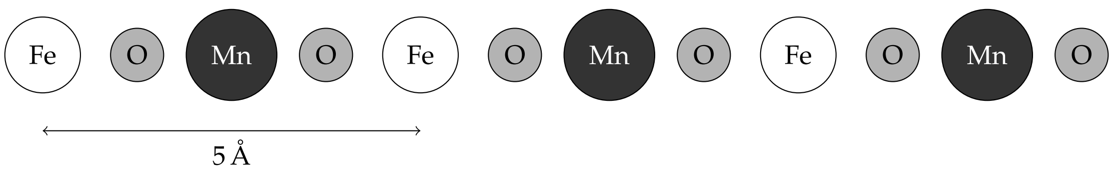
(i) Ferromagnetic at low temperatures



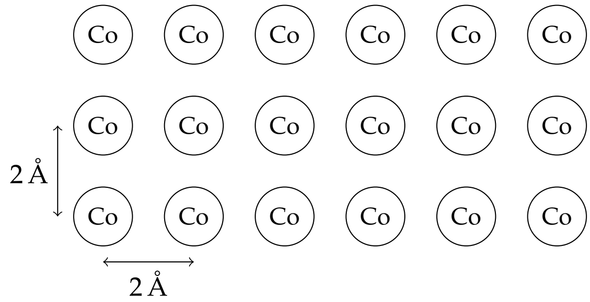
(ii) Antiferromagnetic at low temperatures



(iii) Ferrimagnetic at low temperatures



(b) Now try the opposite problem: to reconstruct a magnetic structure from the observed diffraction peaks. Consider a hypothetical 2D square lattice of magnetic ions: (8)



In each of the following (separate) cases, suggest a pattern of magnetic ordering that would give a magnetic diffraction peak at the specified Q value.

(i) $Q = 1.57\,\text{Å}^{-1}$

(ii) $Q = 2.22\,\text{Å}^{-1}$

Problem 3: Magnetic materials in an external field (15 marks)

(a) For each of the following systems, calculate the external magnetic field B that would have to be applied to achieve a magnetisation one quarter of the saturation value at 400 K. (11)

(i) A spin-$\frac{1}{2}$ paramagnet

(ii) A spin-$\frac{1}{2}$ ferromagnet with Curie temperature $T_C = 375\,\text{K}$
(Hint: use the Weiss mean-field model, and start by calculating λ in terms of T_C.)

(b) Comment on the magnitudes of your answers for these two cases, individually and relative to one another. (4)

Data:

Electronic charge	$e = 1.6022 \times 10^{-19}\,\text{C}$
Planck constant	$h = 6.626 \times 10^{-34}\,\text{J s}$
	$\hbar = h/2\pi = 1.055 \times 10^{-34}\,\text{J s}$
Boltzmann constant	$k_B = 1.3807 \times 10^{-23}\,\text{J K}^{-1}$
Electron mass	$m = 9.109 \times 10^{-31}\,\text{kg}$
Avogadro number	$N_A = 6.022 \times 10^{23}\,\text{mol}^{-1}$
Bohr magneton	$\mu_B = 9.274 \times 10^{-24}\,\text{A m}^2$
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\text{H m}^{-1}$