Chapter 1

Chapter 7 - Problems

1.1 Problems

Problem 1

SD grains of hematite (αFe_2O_3) are precipitating from solution at a temperature of 280K. The coercivity is $\mu_o H_c$= 1 T. Use what you need from Table 1.1 from Chapter 6 and find the diameter of a spherical hematite particle with a relaxation time of 100 seconds.

Problem 2

In the text, you were given a brief discussion of the time required for a magnetic grain to become substantially aligned with the magnetic field in a viscous fluid. For water at room temperature, η is approximately 10^{-3} m^{-1} kg s^{-1}. Calculate the time constant of alignment for saturation values of magnetization for both magnetite and hematite in water. [HINT: use values listed in Table 1.1 from Chapter 6.]

Problem 3

Sometimes rocks are exposed to elevated temperatures for long periods of time (for example during deep burial). The grains with relaxation times (at the elevated temperature) shorter than the exposure time will have acquired a so-called thermo-viscous remanence. In order to demagnetize this remanence on laboratory time scales of, say, 100 seconds, we need to know the blocking temperature on laboratory time scales.

a) Use the curves in Figure **??**a to determine the laboratory blocking temperature of a VRM acquired since the last reversal (0.78 Ma) by a rock remaining at 20° C for magnetite. Do the same for a rock buried for 30 Ma to a depth at temperature 250°C.

b) Hydrothermal activity elevates the temperature of a red sandstone to 225°C for a time interval of 1000 yr and results in formation of thermoviscous remanent magnetization (TVRM). If hematite is the exclusive ferromagnetic mineral in this red sandstone, approximately what temperature of thermal demagnetization is required to unblock (remove) this TVRM? The time at maximum temperature during thermal demagnetization is approximately 30 min.

Problem 4

Relaxation time is controlled by saturation magnetization, coercivity, volume and temperature. Write a program that will draw curves for a given relaxation time for coercivity (on the X axis) versus grain volume (on the y axis). Plot out curves for 100 sec, 1 Myr and 1 Gyr for magnetite and for hematite. Use coercivities from 1 mT to 100 mT.

Table 1.1: Physical properties of magnetic minerals.

Magnetite:	Fe_3O_4
Density = 5197 kg m^{-3}	Dunlop and Özdemir [1997]
Curie temperature = 580°C	Dunlop and Özdemir [1997]
Saturation Magnetization = 92 Am^2kg^{-1}	O'Reilly [1984]
Anisotropy Constant = -2.6 Jkg^{-1}	Dunlop and Özdemir [1997]
Volume susceptibility = $\sim$ 1 SI	O'Reilly [1984]
Typical coercivities are 10's of mT	O'Reilly [1984]
Verwey transition: 110-120 K	Özdemir and Dunlop [1993]
Cell edge = 0.8396 nm	Dunlop and Özdemir [1997]
Maghemite:	γFe_2O_3
Density = 5074 kg m^{-3}	Dunlop and Özdemir [1997]
Curie temperature = 590-675°C	Dunlop and Özdemir [1997]
Saturation Magnetization = 74 Am^2kg^{-1}	Dunlop and Özdemir [1997]
Anisotropy Constant = 0.92 Jkg^{-1}	Dunlop and Özdemir [1997]
Verwey transition: suppressed	Dunlop and Özdemir [1997]
Breaks down to αFe_2O_3: between 250$\rightarrow$ 750°C	Dunlop and Özdemir [1997]

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TM60:	$Fe_{2.4}Ti_{0.6}O_4$
Density = 4939 kg m^{-3}	Dunlop and Özdemir [1997]
Curie temperature = 150°C	Dunlop and Özdemir [1997]
Saturation Magnetization = 24 Am^2kg^{-1}	Dunlop and Özdemir [1997]
Anisotropy Constant = 0.41 Jkg^{-1}	Dunlop and Özdemir [1997]
Coercivity $\sim$ 8 mT	Dunlop and Özdemir [1997]
Verwey transition: suppressed	Dunlop and Özdemir [1997]
Cell edge = 0.8482 nm	Dunlop and Özdemir [1997]
Hematite:	αFe_2O_3
Density = 5271 kg m^{-3}	Dunlop and Özdemir [1997]
Néel temperature = 675°C	O'Reilly [1984]
Saturation Magnetization = 0.4 Am^2kg^{-1}	O'Reilly [1984]
Anisotropy Constant = 228 Jkg^{-1}	Dunlop and Özdemir [1997]
Volume susceptibility = $\sim$ 1.3 x 10^{-3} SI	O'Reilly [1984]
Coercivities vary widely and can be 10's of teslas	Banerjee [1971]
Morin Transition: $\sim$ 250-260 K (for > 0.2 μm)	O'Reilly [1984]
Goethite:	$\alpha FeOOH$
Density = 4264 kg m^{-3}	Dunlop and Özdemir [1997]
Néel temperature: 70 $\rightarrow$ 125°C	O'Reilly [1984]
Saturation Magnetization = $10^{-3} \rightarrow 1$ Am^2kg^{-1}	O'Reilly [1984]
Anisotropy Constant = 0.25 $\rightarrow$ 2 Jkg^{-1}	Dekkers [1989]
Volume susceptibility = $\sim$ 1 x 10^{-3} SI	Dekkers [1989a]
Coercivities can be 10's of teslas	
Breaks down to hematite: 250 $\rightarrow$ 400°C	
Pyrrhotite:	Fe_7S_8
Density = 4662 kg m^{-3}	Dunlop and Özdemir [1997]
Monoclinic:	
Curie temperature = $\sim$ 325°C	Dekkers [1989]
Hexagonal:	
Curie temperature = $\sim$270°C	Dekkers [1988]
Saturation Magnetization = 0.4 -$\sim$ 20 Am^2kg^{-1}	Worm et al. [1993]
Volume susceptibility = $\sim$ 1 x $10^{-3} \rightarrow 1$ SI	Collinson [1983];O'Reilly [1984]
Anisotropy Constant = 20 Jkg^{-1}	O'Reilly [1984]
Coercivities vary widely and can be 100's of mT	O'Reilly [1984]
Has a transition at $\sim$ 34 K	Dekkers et al. [1989]
	Rochette et al. [1990]
Hexagonal pyrrotite: transition near 200°	

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Breaks down to magnetite: $\sim$ 500°C	Dunlop and Özdemir [1997]
Greigite:	Fe_3S_4
Density = 4079 kg m^{-3}	Dunlop and Özdemir [1997]
Maximum unblocking temperature = $\sim$ 330°C	Roberts [1995]
Saturation Magnetization = $\sim$ 25 Am^2kg^{-1}	Spender et al. [1972]
Anisotropy Constant = -0.25 Jkg^{-1}	Dunlop and Özdemir [1997]
Coercivity 60$\rightarrow$> 100 mT	Roberts [1995]
Has high M_r/χ ratios $\sim$ 70 x 10^3 Am^{-1}	Snowball and Thompson [1990]
Breaks down to magnetite: $\sim$ 270-350°C	Roberts [1995]