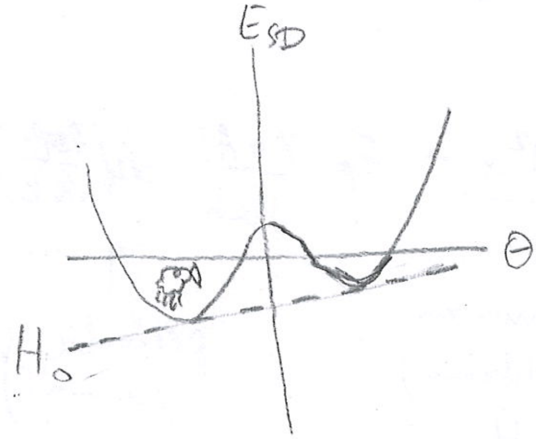
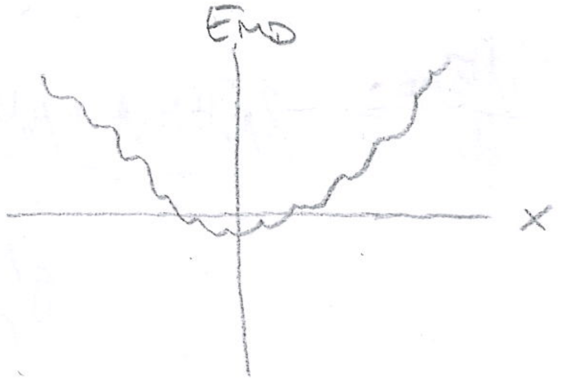
3 Blocking

Review

$$E_{SD} = -\mu_0 M_S V H \cos(\theta - \varphi) + \frac{1}{2}\mu_0 H_K M_S V \sin^2\theta$$

$$E_{MD} = -2\mu_0 H_0 M_S A x + 2\mu_0 N M_S^2 A^2 x^2 + \gamma_w A(n-1) + E_p \sin^2\left(\frac{2\pi A x}{V_{bulk}}\right)$$





Exercise: find the location of the energy minima (i.e. where "the sheeps" are staying)

tip: $\frac{d}{d\theta}\cos(\theta-\varphi) = -\sin(\theta-\varphi)$,

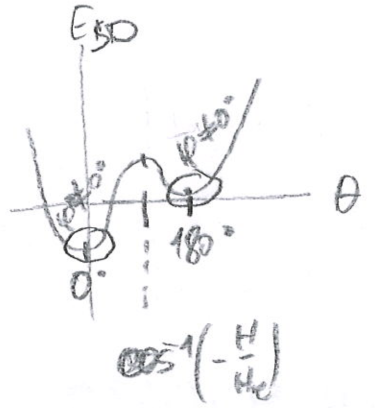
$\frac{d}{d\theta}\sin^2(\theta) = 2\sin(\theta)\cos(\theta)$

Solution: $\frac{dE_{SD}}{d\theta} = \mu_0 M_S V H \sin(\theta - \varphi) + \mu_0 H_K M_S V \sin(\theta)\cos(\theta) \overset{!}{=} 0$

$\Rightarrow H \sin(\theta - \varphi) + H_K \sin\theta \cos\theta = 0$

for $\varphi = 0°$ $\Rightarrow$ $\cos\theta = -\frac{H}{H_K}$ $\leftarrow$ maximum

or $\sin(\theta) = 0$ $\Rightarrow$ $\theta = 0°$ or $\theta = 180°$ $\leftarrow$ minima

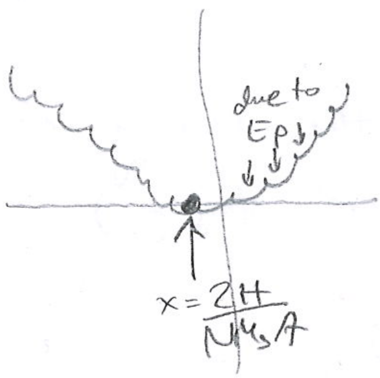


for $\varphi = 0°$ there are 2 solutions, $0°$ and $180°$. This is the irreversible magnetization (magnetization stays in local minima).

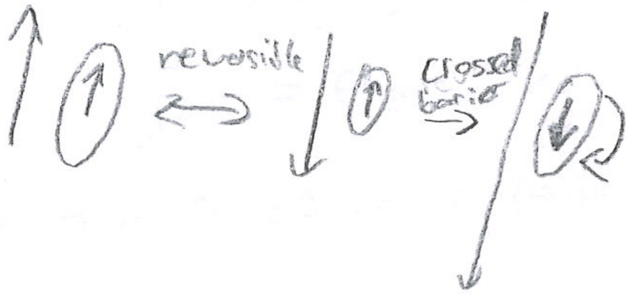
for $\varphi \neq 0°$ the two solutions depend on H: reversible magnetization (

$$\frac{dE_{MD}}{dx} = \underbrace{-2\mu_0 H M_s A + \mu_0 N M_s^2 A^2 x}_{\substack{\text{global minima} \\ \text{(equilibrium)} \\ x = \frac{2H}{NM_sA}}} + E_p \frac{2\pi A}{V_{Bark}} \sin\left(\frac{2\pi A x}{V_{Bark}}\right) \overset{!}{=} 0$$

periodic zeros (minima)



Blocking: magnetisation only moves within "valley" (reversible) but cannot "jump" over the "mountain" (energy barrier).



Sheep in the sun

Exercise: How high does the sheep need to jump to get over the mountain?

1) Height of the valley?
2) Height of the mountain peak?

Solution:

1) $E_{SD}^{min} = \mp\mu_0 M_s V H$

2) $E_{SD}^{max} = -\mu_0 M_s V H \cdot \left(-\frac{H}{H_K}\right) + \frac{1}{2}\mu_0 H_K M_s V \left(1 + \left(-\frac{H}{H_K}\right)^2\right)$

$$= \mu_0 M_s V \frac{H^2}{H_K} + \frac{1}{2}\mu_0 H_K M_s V - \frac{1}{2}\mu_0 M_s V \frac{H^2}{H_K}$$

$$= \frac{1}{2}\mu_0 H_K M_s V \left(1 + \frac{H^2}{H_K^2}\right)$$

$$\Rightarrow \Delta E = E_{SD}^{max} - E_{SD}^{min}$$

$$\boxed{\Delta E = \frac{1}{2}\mu_0 H_K M_s V \left(1 \pm \frac{H_0}{H_K}\right)^2}$$

if the sheep can jump higher than ΔE_{21}, it can cross over from 2 to 1.

Where does the energy for jumping come from?

Temperature $\longrightarrow$ Thermal energy

$$T\,[K, {}^\circ C] \longrightarrow k_B \cdot T \quad [J]$$

$\uparrow$ Boltzmann constant

$$k_B = 1.38 \cdot 10^{-23}\ J/K$$

<u>Question</u>: What field is necessary so the sheep can <u>walk</u> over rather than jump?

<u>Answer</u>: $\Delta E = 0$

$$\Rightarrow \frac{1}{2}\mu_0 H_K M_S V \left(1 \pm \frac{H}{H_K}\right)^2 = 0$$

$$\Rightarrow H = \pm H_K$$

($H = +H_K \rightarrow$ sheep can walk left,
$H = -H_K \rightarrow$ sheep can walk right)