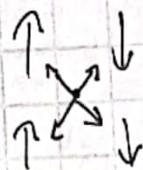


P7

a. Red cuadrada



$$H = -J \sum_{\langle i,j,k,l \rangle} \sigma_i \sigma_j \sigma_k \sigma_l$$

Campo medio $\sigma_i \approx m + \delta\sigma_i \rightarrow$ Orden $\delta\sigma_i^2$ se desprecia

$$\Rightarrow H = -J \sum_{\langle \rangle} (m + \delta\sigma_i)(m + \delta\sigma_j)(m + \delta\sigma_k)(m + \delta\sigma_l)$$

$$= -J \sum_{\langle \rangle} (m^4 + m^3(\delta\sigma_i + \delta\sigma_j + \delta\sigma_k + \delta\sigma_l) + m^2(\delta\sigma_i^2 + \delta\sigma_j^2 + \delta\sigma_k^2 + \delta\sigma_l^2) + \dots)$$

$$= -J \sum_{\langle \rangle} (m^4 + m^3(\delta\sigma_i + \delta\sigma_j + \delta\sigma_k + \delta\sigma_l)) \rightarrow i,j,k,l \text{ mudos}$$

$$\Rightarrow = -J \sum_{\langle \rangle} (m^4 + 4m^3\delta\sigma_i) ; \delta\sigma_i = \sigma_i - m$$

$$\Rightarrow = -J \sum_{\langle \rangle} (m^4 + 4m^3\sigma_i - 4m^4) = -J \sum_{\langle \rangle} (4m^3\sigma_i - 3m^4)$$

$$\sum_{\langle \rangle} 1 = N \wedge \sum_{\langle \rangle} \sigma_i = \sum_i \sigma_i$$

$$\Rightarrow H = 3JNm^4 - 4m^3J \sum_i \sigma_i$$

$$Z = \sum_{\{\sigma_i\}} e^{-3\beta JNm^4} e^{4\beta Jm^3 \sum_i \sigma_i} ; \sum \rightarrow \text{Suma sobre posibles } \sigma_i (\sigma_i = \pm 1)$$

$$Z = e^{-3\beta JNm^4} \prod_{i=1}^N \sum_{\sigma_i = \pm 1} e^{4\beta Jm^3 \sigma_i} ; e^{4\beta Jm^3 \sum_i \sigma_i} = \prod_{i=1}^N e^{4\beta Jm^3 \sigma_i}$$

PREPARTE

$$\Rightarrow Z = e^{-3\beta J N m^4} \prod_{i=1}^N \left(\overbrace{e^{4\beta J m^3} + e^{-4\beta J m^3}}^{2 \cosh(4\beta J m^3)} \right)$$

$$= e^{-3\beta J N m^4} (2 \cosh(4\beta J m^3))^N$$

$$\Rightarrow F = -\frac{1}{\beta} \ln(Z) = 3J N m^4 - \frac{N}{\beta} \ln(2 \cosh(4\beta J m^3))$$

$$\Rightarrow \frac{\delta F}{\delta m} = 0 \Leftrightarrow 0 = 12J N m^3 - \frac{N}{2 \cosh(4\beta J m^3)} \cdot 2 \sinh(4\beta J m^3) \cdot 12\beta J m^2$$

$$\Rightarrow 0 = \cancel{12J N m^3} - \cancel{12J N m^2} \tanh(4\beta J m^3)$$

$$\Rightarrow m = \tanh(4\beta J m^3) //$$