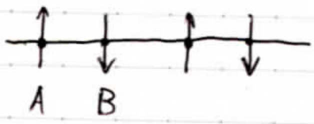
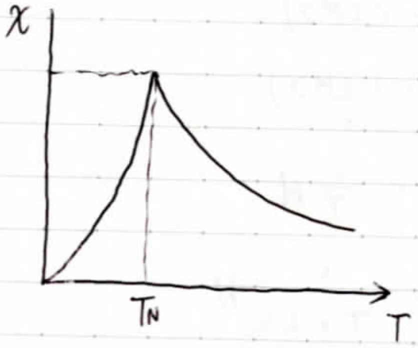
2.9 反強磁性





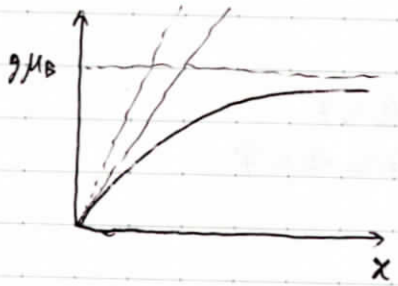
$$\langle M_A \rangle = -\langle M_B \rangle = \langle M \rangle$$

$$H = \sum_{\langle i,j \rangle} 2 J_{AF} \mathbf{S}_i \cdot \mathbf{S}_j$$

$$= \sum_j \frac{2z J_{AF}}{(g\mu_B)^2} \langle M_i \rangle M_j$$

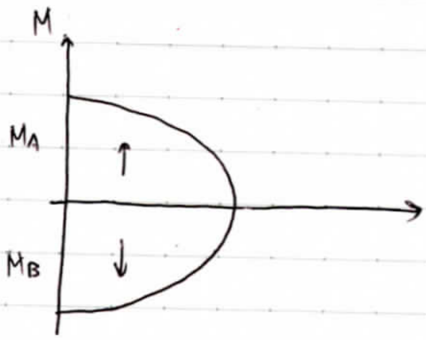
$$= \boxed{-\underbrace{\sum_j \frac{2z J_{AF}}{(g\mu_B)^2} \langle M \rangle}_{H_{eff}}} M_j$$

強磁性と等価



$$\chi = \frac{g\mu_B S H_{eff}}{k_B T}$$

$$k_B T_{N\,m} = \frac{2}{3} J z S(S+1)$$



$$\langle M \rangle = \chi (H + H_{eff})$$
$$= \chi (H - \lambda \langle M \rangle)$$
$$= \frac{c}{T} (H - \lambda \langle M \rangle)$$

$$\left(1 + \frac{c\lambda}{T}\right) \langle M \rangle = \frac{c}{T} H$$

$$\langle M \rangle = \frac{c}{T + c\lambda} H$$

$$\chi = \frac{c}{T + c\lambda}$$ キュリー・ワイス則

$$c = \frac{g^2 \mu_B^2 S(S+1)}{3 k_B}, \quad \lambda = \frac{2zJ}{(g\mu_B)^2}$$

$$c\lambda = \frac{2zJS(S+1)}{3k_B} = T_{Nm}$$

$$M_q = \frac{1}{N} \Sigma_j M_j e^{iqa_j}$$

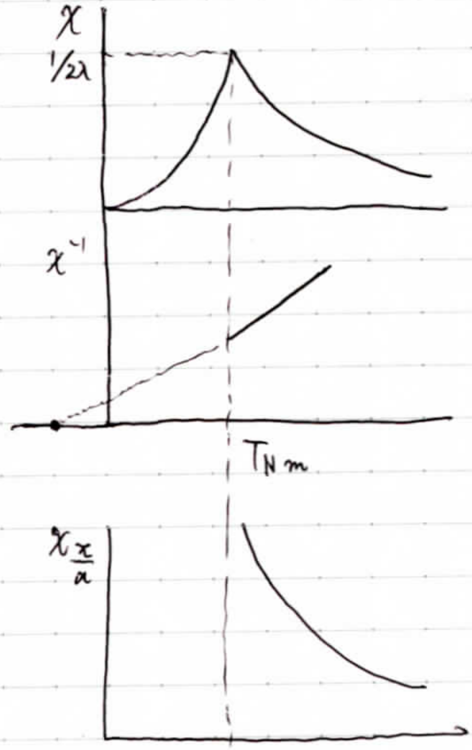
$$H_q = H_{q0} e^{iqa_j}$$

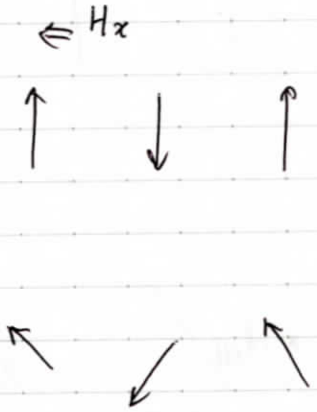
$$\chi = \frac{M_q}{H_q}$$

$q = 0$ 一様磁化率

$q = \frac{\pi}{a}$ 反強磁性 磁化率

$$\chi\left(\frac{\pi}{a}\right) \to \infty \quad \text{at } T_{Nm}$$

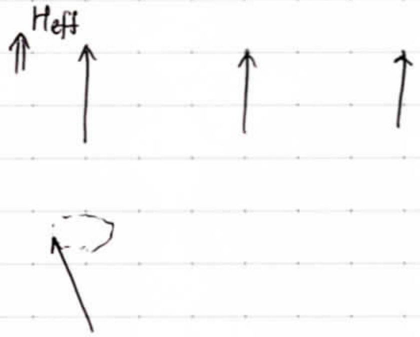




$$H = 2\lambda M_x$$

$$\frac{M_x}{H_x} = \frac{1}{2\lambda} \quad 一定$$

2.10 スピン波



$$\hbar \frac{d\boldsymbol{S}_i}{dt} = \boldsymbol{M}_i \times \boldsymbol{H}_{eff} \qquad \frac{\boldsymbol{M}}{g\mu_B} = \boldsymbol{S}$$

$$= g\mu_B \boldsymbol{S}_i \times \frac{2zJ}{g\mu_B}\left(\boldsymbol{S}_{i-1} + \boldsymbol{S}_{i+1}\right)$$

$$= 2zJ\left(\boldsymbol{S}_i \times \boldsymbol{S}_{i-1} + \boldsymbol{S}_i \times \boldsymbol{S}_{i+1}\right)$$

$$\boldsymbol{S}_i = \boldsymbol{S}_0 + \delta\boldsymbol{S}_i$$

$$\hbar \frac{d\delta\boldsymbol{S}_i}{dt} = 2zJ\left\{(\delta\boldsymbol{S}_i - \delta\boldsymbol{S}_{i-1}) \times \boldsymbol{S}_0 + (\delta\boldsymbol{S}_i - \delta\boldsymbol{S}_{i+1}) \times \boldsymbol{S}_0\right\}$$

$$\delta\boldsymbol{S}_i = \boldsymbol{A}_q e^{i(q \cdot ia - \omega t)}$$

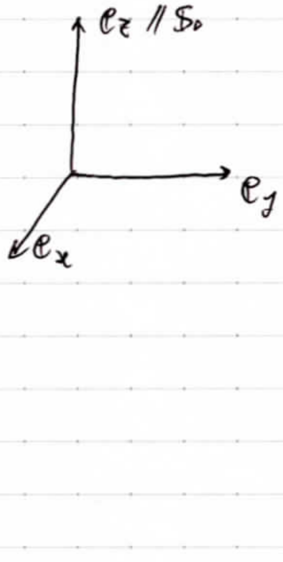
$$-i\hbar\omega \boldsymbol{A}_q = 2zJ\left(2 - e^{iqa} - e^{-iqa}\right)\boldsymbol{A}_q \times \boldsymbol{S}_0$$

$$= 4zJ(1 - \cos qa)\, \boldsymbol{A}_q \times \boldsymbol{S}_0$$

$$\boldsymbol{A}_q = \alpha(\boldsymbol{e}_x - i\boldsymbol{e}_y)$$

$$-i\hbar\omega = -i\, 4zJS(1 - \cos qa)$$; $\boldsymbol{e}_x$ について

$$\hbar\omega = 4zJS(1 - \cos qa)$$



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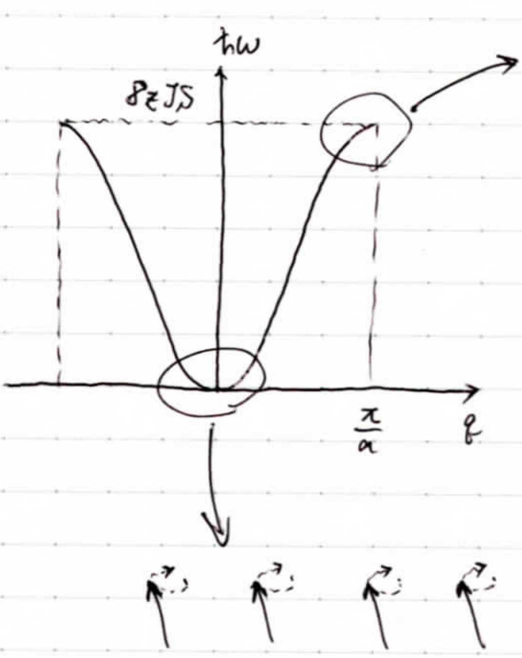
Date



スピン波

量子化 → マグノン