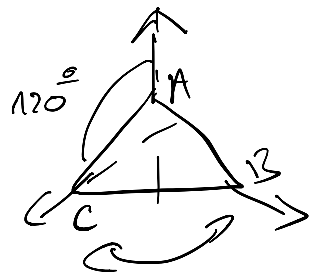
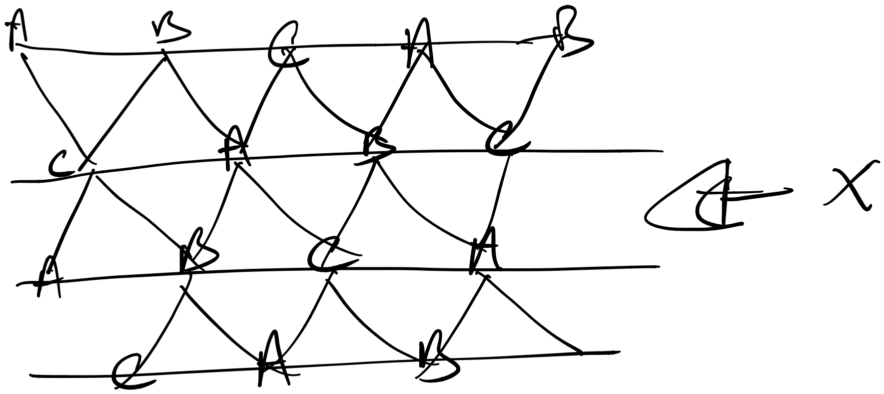
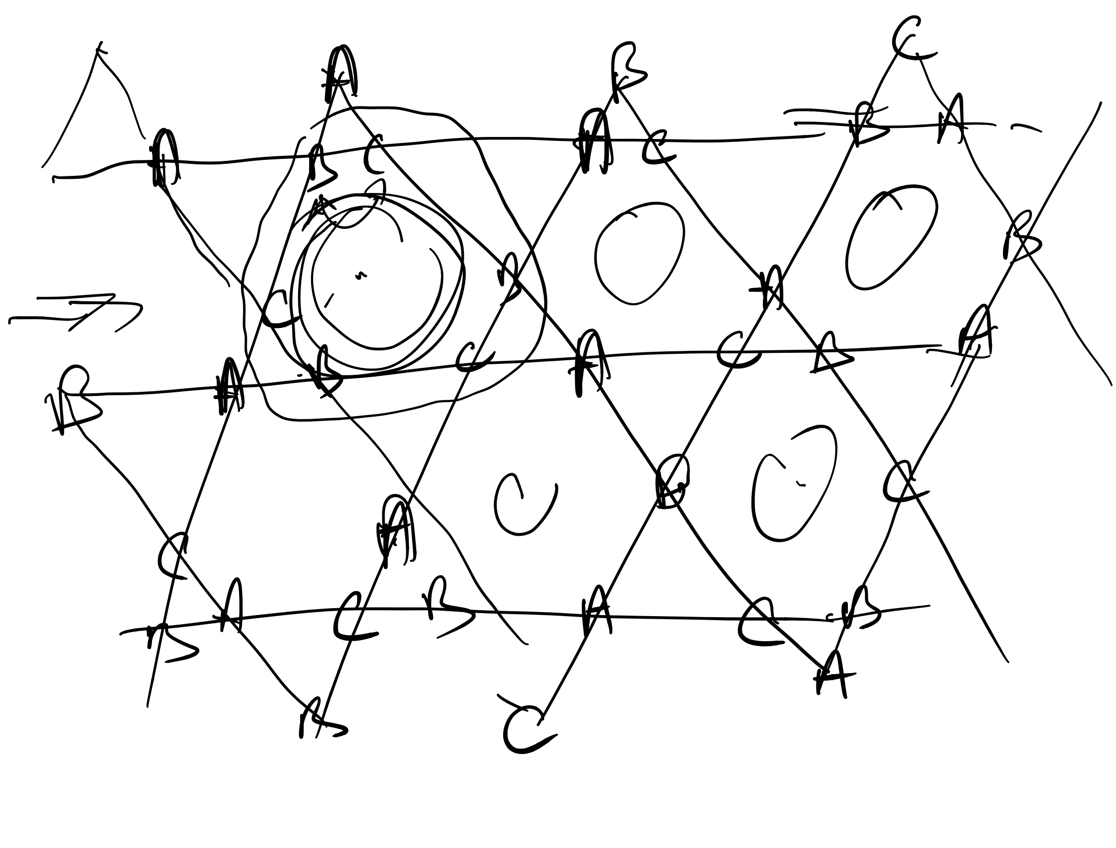
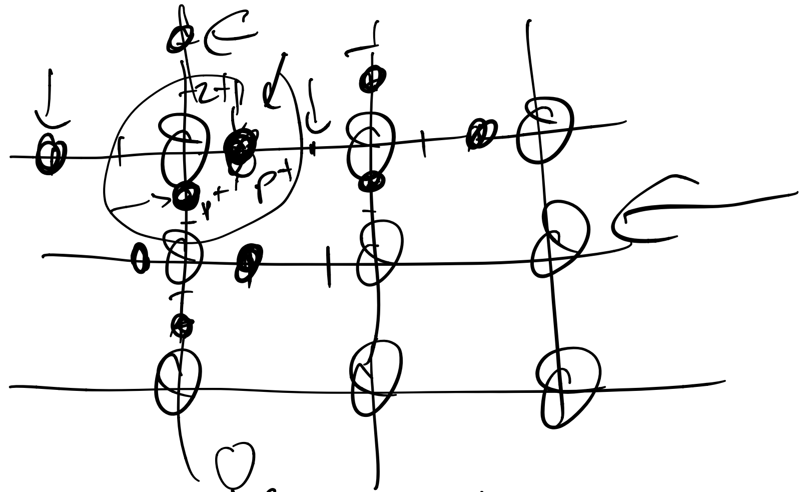

120°
A
B
C

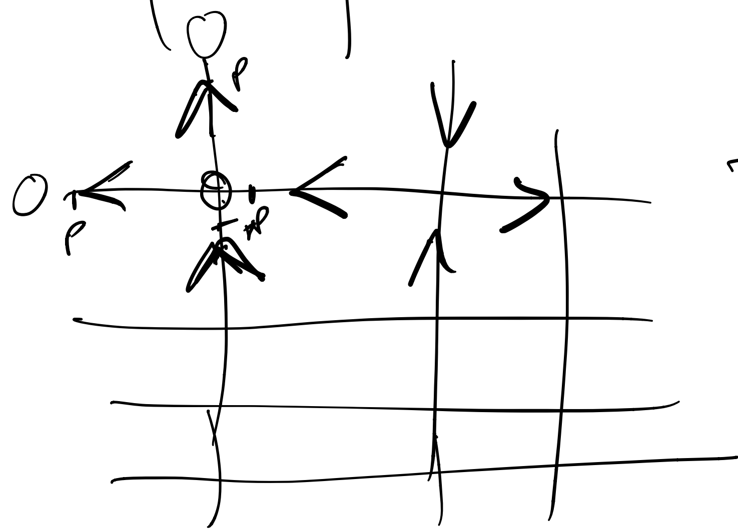

A


A B C A B
C A B C
A B C A
C A B
X



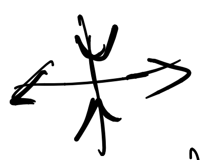
$O + 2H$ ice rules.

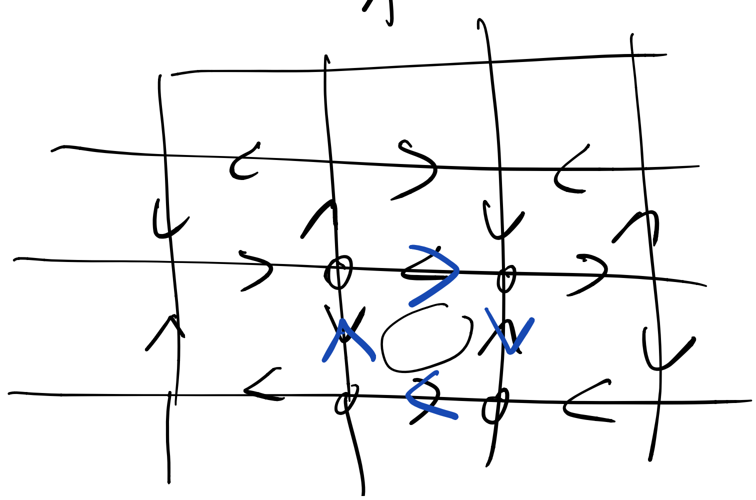


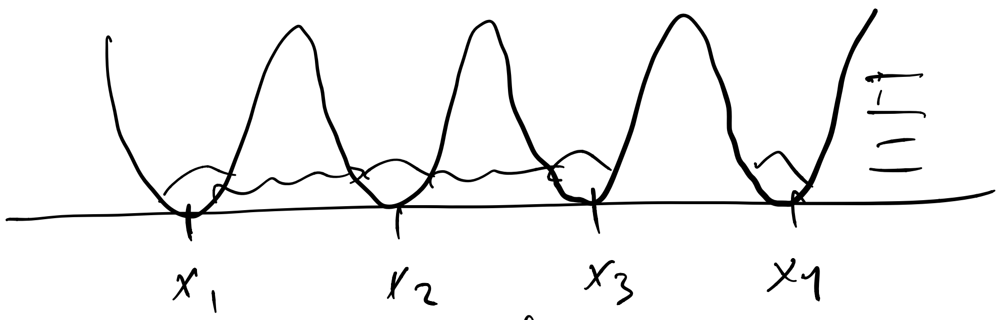


$\vec{\nabla} \cdot \vec{B} = \vec{0}$

ice rules







degeneracy lifting.

4] El R.G. perturbativo para teorías de campos

$$S_{G.L} = \int d^D\vec{r} \left[\frac{K}{2} (\vec{\nabla}\phi)^2 + \frac{t}{2}\phi^2 + \mu\phi^4 \right]$$

antes $\frac{c}{2}$ antes $\frac{a_2}{2}$ antes $\frac{a_4}{4}$

$$S_{GL} = S_0 + U$$

donde $S_0 = \int d^D\vec{r} \left[\frac{K}{2} (\vec{\nabla}\phi)^2 + \frac{t}{2}\phi^2 \right]$

$$U = \int d^D\vec{r}\, \mu_4 \phi^4 + \mu_6 \phi^6 + \mu_8 \phi^8$$

Cambio $\vec{r} \to b\vec{r}$, $\partial_\mu \to \frac{1}{b}\partial_\mu$

$\vec{q}$ variables de Fourier $\left(e^{i\vec{q}\cdot\vec{r}}\right)$

$\vec{q} \to \frac{1}{b}\vec{q}$, $K \to K$, $\phi \to b^{\frac{2-D}{2}}\phi$

$b^{1-\frac{D}{2}}\phi$

$t \to b^{-2} t$

$u \to b^{4-D} u$

$u_6 \to b^{6-2D} u_6$

$u_8 \to b^{8-3D} u_8$

etc...

$\hat{\phi}(\vec{q}) \equiv m(\vec{q})$

cambio de nombre.

$$m(\vec{q}) = \int d^D\vec{r}\, e^{i\vec{q}\cdot\vec{r}} \phi(\vec{r})$$

$$\phi(\vec{r}) = \sum_{\vec{q}}' \frac{e^{-i\vec{q}\cdot\vec{r}}}{V} m(\vec{q}) \xrightarrow[V\to\infty]{} \int \frac{d^D\vec{q}}{(2\pi)^D} e^{-i\vec{q}\cdot\vec{r}} m(\vec{q})$$

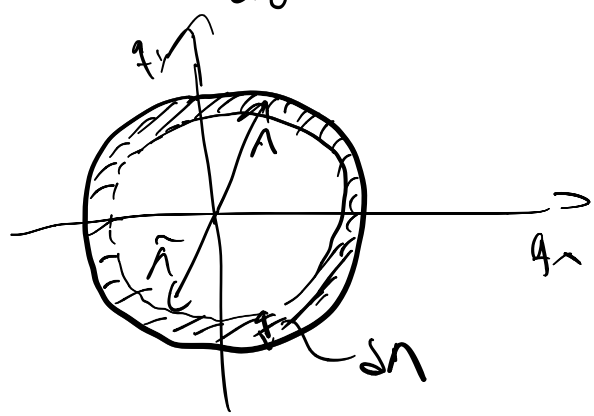
$$S_0 = \sum_{\vec{q}}' \left(\frac{t + K\vec{q}^2}{2V}\right) |m(\vec{q})|^2$$

$$\xrightarrow[V\to\infty]{} \int \frac{d^D\vec q}{(2\pi)^D} \frac{(t+K\vec q^2)}{2} |m(\vec q)|^2$$

$$U = \mu \int \frac{d^D\vec q_1\, d^D\vec q_2\, d^D\vec q_3}{(2\pi)^{3D}} m(\vec q_1)\, m(\vec q_2)\, m(\vec q_3)\, m(-\vec q_1-\vec q_2-\vec q_3)$$

→ "momentum shell renormalization"

$|\vec q| < \Lambda \sim \frac{1}{a_0}$, a_0 distancia entre sitios.



→ nuevo cut-off $\tilde\Lambda = \Lambda - d\Lambda$

$$S_\Lambda \to \tilde S_{\tilde\Lambda} \to \tilde{\tilde S}_{\tilde{\tilde\Lambda}} \to - - - ?$$

$\tilde\Lambda = \frac{\Lambda}{b}$ → integran sobre los $m(\vec q)$

$\forall q \quad \frac{\Lambda}{b} < |\vec q| \le \Lambda$

$$Z = \int \mathcal{D}\phi \, e^{-S_0 - U}$$

$$= \int \prod_{\vec{q}} dm(\vec{q}) \, e^{-S} \rightarrow \int \tilde{\prod_{\vec{q}}} dm_{\vec{q}} \, e^{-S_{eff}}$$

$$\tilde{\prod_{\vec{q}}} : |\vec{q}| < \frac{\Lambda}{b}$$

$$\prod_{\vec{q}} = \prod_{|\vec{q}| < \frac{\Lambda}{b}} \prod_{\frac{\Lambda}{b} < |\vec{q}| < \Lambda}$$

$$m(\vec{q}) = \begin{cases} \tilde{m}(\vec{q}) & \text{if } |\vec{q}| \leq \frac{\Lambda}{b} \\ \sigma(\vec{q}) & \text{if } \frac{\Lambda}{b} < |\vec{q}| \leq \Lambda \end{cases}$$

$$Z = \int \tilde{\prod_{\vec{q}}} d\tilde{m}(\vec{q}) \prod_{\frac{\Lambda}{b} < \vec{q} < \Lambda} d\sigma(\vec{q}) \; e^{-\int_{|\vec{q}| < \frac{\Lambda}{b}} \frac{d^D \vec{q}}{(2\pi)^D} \left(\frac{t + K\vec{q}^{\,2}}{2}\right) |\tilde{m}(\vec{q})|^2 - \int_{\frac{\Lambda}{b} < |\vec{q}| \leq \Lambda} \frac{d^D \vec{q}}{(2\pi)^D} \left(\frac{t + K\vec{q}^{\,2}}{2}\right) |\sigma(\vec{q})|^2}$$

$$\times e^{-U[m, \sigma]}$$

$$d^D \vec{q} \; (t + K\vec{q}^{\,2}) \, |\sigma(\vec{q})|^2$$

$$\text{def} \quad Z_\sigma = \int \prod d\sigma(\vec{q})\, e^{-\int_{\frac{\Lambda}{b}<q<\Lambda} \frac{d^D q}{(2\pi)^D} \left(\frac{t+Kq^2}{2}\right)|\sigma(\vec{q})|^2}$$

$$\delta F_b^0 = \ln Z_\sigma$$

$$\langle \mathcal{O} \rangle_\sigma \underset{\text{def}}{\equiv} \frac{1}{Z_\sigma} \int \prod d\sigma(\vec{q})\, \mathcal{O}\, e^{-\int \cdots}$$

$$Z = \int \prod d\tilde{m}(\vec{q}) \prod d\sigma(\vec{q})\, e^{-S_0 - U}$$

$$Z_{eff} = \int \prod d\tilde{m}(\vec{q})\, e^{-S_0(\tilde{m})} \underbrace{Z_\sigma \langle e^{-U(m,\sigma)} \rangle_\sigma}_{e^{\cdots}}$$

$$= \int \prod d\tilde{m}(\vec{q})\, e^{-S_{eff}(\tilde{m})}$$

$$S_{eff} = \int_{|\vec{q}| \le \frac{\Lambda}{b}} \frac{d^D q}{(2\pi)^D} \left(\frac{t+K\vec{q}^2}{2}\right) |\tilde{m}(\vec{q})|^2 + \delta f_b^0 - \ln \langle e^{-U} \rangle_\sigma$$

$$\ln \langle e^{-U} \rangle_\sigma = -\langle U \rangle_\sigma + \frac{1}{2}\left(\langle U^2 \rangle_\sigma - \langle U \rangle_\sigma^2\right) + \cdots$$

$- \langle U \rangle_\sigma$

$$\langle U \rangle_\sigma = \mu \int_0^\Lambda \frac{d\vec{q}_1\, d\vec{q}_2\, d\vec{q}_3\, d\vec{q}_4}{(2\pi)^{4D}} (2\pi)^D \delta(\vec{q}_1+\vec{q}_2+\vec{q}_3+\vec{q}_4)$$

$$\Big\langle \underbrace{[\hat{m}(\vec{q}_1) \text{ ó } \sigma(\vec{q}_1)]}_{1} [\hat{m}(\vec{q}_2) \text{ ó } \sigma(\vec{q}_2)] \underbrace{[\ 3\ ] [\ 4\ ]}\Big\rangle_\sigma$$

<u>Obs</u>:

* los términos con un número impar de σ dan "0" $\langle \sigma^3 \rangle = \langle \sigma \rangle = 0$

- * potencias pares de σ

$0 \to \hat{m}(\vec{q}_1)\, \hat{m}(\vec{q}_2)\, \hat{m}(\vec{q}_3)\, \hat{m}(\vec{q}_4)$

$\hookrightarrow \mu \tilde{\phi}^4$ para S_{eff}.

* 4 σ (ninguna m) $\to$ cte que se agrega a δF_b^0

* $\underline{2\sigma}$ y 2 m $\to$ 12 posibilidades.

$$\langle \sigma(\vec{q}_1)\,\sigma(\vec{q}_2)\rangle = \frac{\delta(\vec{q}_1+\vec{q}_2)\,(2\pi)^D}{t+k\,|\vec{q}_1|^2}$$

$$-\langle M \rangle_\sigma = \text{cte}\; -12\mu \int \frac{d\vec{q}_1 \ldots d\vec{q}_4}{(2\pi)^{4D}}\,(2\pi)^D\, \delta(\vec{q}_1+\ldots+\vec{q}_4)$$

$\vec{q}_4 = -\vec{q}_3$

$$\frac{(2\pi)^D\,\delta(\vec{q}_1+\vec{q}_2)}{t+k\,\vec{q}_1^{\,2}}\;\tilde{m}(\vec{q}_3)\,\tilde{m}(\vec{q}_4) \qquad \tilde{m}(\vec{q}_4) = \tilde{m}^*(\vec{q}_3)$$

$$= -12\mu \int_{|\vec{q}|<\frac{\Lambda}{b}} \frac{d^D\vec{q}}{(2\pi)^D}\,|\tilde{m}(\vec{q})|^2 \times \int_{\frac{\Lambda}{b}<|\vec{k}|<\Lambda} \frac{d^D\vec{k}}{(2\pi)^D}\,\frac{1}{t+k\vec{k}^2}$$

Seg $(\tilde{t}, k, \hat{u})$

Con $\boxed{\tilde{t} = t + 12\mu \int_{\frac{\Lambda}{b}}^{\Lambda} \frac{d^D\vec{k}}{(2\pi)^D}\,\frac{1}{t+k\vec{k}^2}}$

→ observamos es una renormalización del "t"

$\sim T-T_c$ → renormalización de T_c

con el cambio de escala

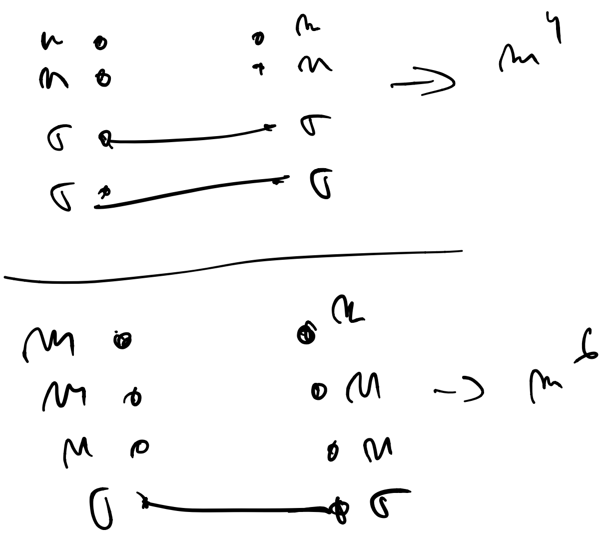
$$\bar{\pi} \to b\,\tilde{\bar{n}} \qquad \bar{q} \to b^{-1}\,\tilde{\bar{q}}$$

$$m(\bar{q}) \to \underbrace{b^{1+\frac{D}{2}}\,\tilde{m}(\bar{q}')}_{} \qquad \phi \to b^{1-\frac{D}{2}}\phi$$

$$t \to b^2\,\tilde{t} \qquad \hat{k} = k\ , \quad \mu = b^{4-D}\,\hat{\mu}$$

$$\boxed{\begin{aligned} \tilde{t}_b &= b^2\left[t + 12\mu \int^{\hat{b}} \frac{d^D \bar{k}}{(2\pi)^D}\,\frac{1}{t + K\bar{k}^2}\right] \\ \hat{\mu}_b &= b^{4-D}\mu + B\mu^2 \end{aligned}}$$

$\phi^4 \quad \phi^4 \to$



$$\tilde{\mu}_{6b} = b^{6-2D}\,\mu_6 + \dots \mu^2 \qquad D = 3$$

$$\hat{\mu}_{8b} = b^{8-3D}\mu_8 + \mu^3 + \cdots$$

$D \sim 4$

$$6-2D < 0 \qquad D = 4, 3,$$

$$8-3D < 0$$

R.G. $\tilde{\mu}_6, \hat{\mu}_8, \tilde{\mu}_{10} \xrightarrow[R.G.]{} 0$

→ términos irrelevantes.

para $D = 3$, el μ_6 está, es marginal,

pero da contribuciones subdominantes