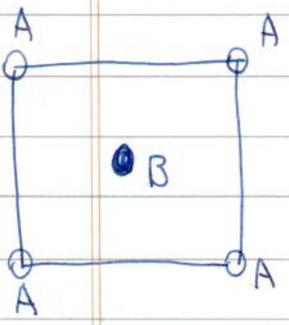
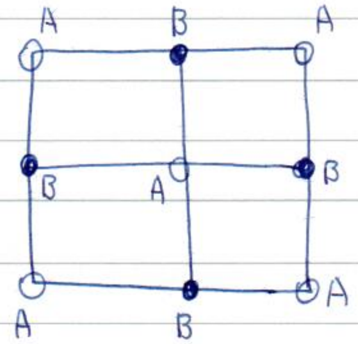
2016/9/20 (화). (1)

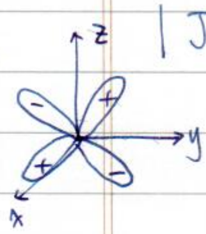




$$\left|J_z=\tfrac{1}{2}\right\rangle = \frac{1}{\sqrt{3}}\left(|d_{yz}\downarrow\rangle + i\,|d_{zx}\downarrow\rangle + |d_{xy}\uparrow\rangle\right)$$

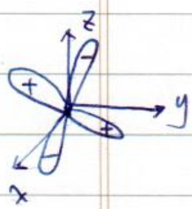
$$\left|J_z=-\tfrac{1}{2}\right\rangle = \frac{1}{\sqrt{3}}\left(|d_{yz}\uparrow\rangle - i\,|d_{zx}\uparrow\rangle - |d_{xy}\downarrow\rangle\right)$$

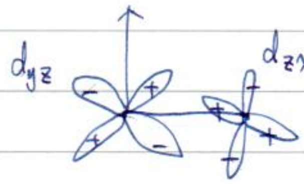
d_{yz}



$$H = 2t_0(\cos k_x + \cos k_y)\,\sigma_0\tau_0 + 4t'\left(\cos\frac{k_x}{2}\cos\frac{k_y}{2}\right)\sigma_0\tau_x + 4t_{1d}\left(\cos\frac{k_x}{2}\cos\frac{k_y}{2}\right)\sigma_z\tau_y$$

d_{zx}





$$C^\dagger_{i,A}C_{i+\frac{1}{2},B} + C^\dagger_{i+\frac{1}{2},B}C_{i,A}$$

$(d_{yz}|d_{zx}) = +t'$

$\left(t_\sigma\cos^2\theta - t_\pi\sin^2\theta\right)\cos\varphi$

$$\sum_i \Big(C^\dagger_{i,A}C_{i+\frac{\hat{x}}{2}+\frac{\hat{y}}{2},B} + C^\dagger_{i+\frac{\hat{x}}{2}+\frac{\hat{y}}{2},A}C_{i,B} + C^\dagger_{i,A}C_{i-\frac{\hat{x}}{2}+\frac{\hat{y}}{2},B} + C^\dagger_{i-\frac{\hat{x}}{2}+\frac{\hat{y}}{2},B}C_{i,A}$$
$$+ C^\dagger_{i,A}C_{i-\frac{\hat{x}}{2}-\frac{\hat{y}}{2},B} + C^\dagger_{i-\frac{\hat{x}}{2}-\frac{\hat{y}}{2},B}C_{i,A} + C^\dagger_{i,A}C_{i+\frac{\hat{x}}{2}-\frac{\hat{y}}{2},B} + C^\dagger_{i+\frac{\hat{x}}{2}-\frac{\hat{y}}{2},B}C_{i,A}\Big)$$

$\approx>$

$$C_i = \frac{1}{\sqrt{N}}\sum_k C_k e^{i\vec{k}\cdot\vec{r}_i}$$

$$\sum_i \frac{1}{N}\sum_{\vec{k},\vec{k}'} C^\dagger_{k,A}e^{-i\vec{k}\cdot\vec{r}_i}\; C_{k',B}e^{i\vec{k}'\cdot(\vec{r}_i+\frac{\hat{x}}{2}+\frac{\hat{y}}{2})}$$

$$C^\dagger_{k,A}e^{-i\vec{k}\cdot\vec{r}_i}\; C_{k',B}e^{i\vec{k}'(\vec{r}_i-\frac{\hat{x}}{2}-\frac{\hat{y}}{2})}$$

$$C^\dagger_{k,A}C_{k,B}\,e^{i\vec{r}_i(\vec{k}'-\vec{k})}\left(e^{i\left(\frac{k_x}{2}+\frac{k_y}{2}\right)} + e^{-i\left(\frac{k_x}{2}+\frac{k_y}{2}\right)} + e^{i\left(\frac{k_x}{2}-\frac{k_y}{2}\right)} + e^{-i\left(\frac{k_x}{2}-\frac{k_y}{2}\right)}\right)$$

$$-it' C^\dagger_{i,A,yz}\, C_{i+\frac{\hat{x}}{2}+\frac{\hat{y}}{2},B,zx} - it' C^\dagger_{i,A,yz}\, C_{i-\frac{\hat{x}}{2}+\frac{\hat{y}}{2},B,zx}$$

$$-it' C^\dagger_{i,A,yz}\, C_{i-\frac{\hat{x}}{2}-\frac{\hat{y}}{2},B,zx} - it' C^\dagger_{i,A,yz}\, C_{i+\frac{\hat{x}}{2}-\frac{\hat{y}}{2},B,zx}$$

$$= -it' \Big(\sum_i \sum_{k,k'} C^\dagger_{k,A,yz}\, e^{-i\vec{k}\cdot\vec{r}_i}\, C_{k',B,zx}\, e^{i\vec{k}'\cdot(\vec{r}_i+\frac{\hat{x}}{2}+\frac{\hat{y}}{2})}$$

$$e^{i\vec{r}_i(\vec{k}'-\vec{k})}\, e^{i(\frac{\vec{k}_x}{2}+\frac{k_y}{2})}$$

$$+ C^\dagger_{k,A,yz} C_{k',B,zx}\, e^{-i\vec{k}\cdot\vec{r}_i}\, e^{i\vec{k}'\cdot(\vec{r}_i-\frac{\hat{x}}{2}+\frac{\hat{y}}{2})}$$

$$+ C^\dagger_{k,A,yz} C_{k',B,zx}\, e^{-i\vec{k}\cdot\vec{r}_i}\, e^{i\vec{k}'\cdot(\vec{r}_i-\frac{\hat{x}}{2}-\frac{\hat{y}}{2})}$$

$$+ C^\dagger_{k,A,yz} C_{k',B,zx}\, e^{-i\vec{k}\cdot\vec{r}_i}\, e^{i\vec{k}'\cdot(\vec{r}_i+\frac{\hat{x}}{2}-\frac{\hat{y}}{2})} \Big)$$

$$= \cancel{i}t' \Big(\sum_k \underbrace{\Big(e^{i(\frac{k_x}{2}+\frac{k_y}{2})} + e^{i(-\frac{k_x}{2}+\frac{k_y}{2})} + e^{-i(\frac{k_x}{2}+\frac{k_y}{2})} + e^{-i(\frac{k_x}{2}-\frac{k_y}{2})} \Big)}_{i} \Big).$$

$$\therefore\ 4t_{1d} \underset{\cos}{\cancel{\ }} \frac{k_x}{2} \underset{\cos}{\cancel{\ }} \frac{k_y}{2}\, \sigma_z \tau_y$$

2016 / 9 / 20 (화) (3)

$$H_{bilayer} = 2t_0(\cos k_x + \cos k_y)\,\sigma_0\tau_0\nu_0 + 4t'\left(\cos\frac{k_x}{2}\cos\frac{k_y}{2}\right)\sigma_0\tau_x\nu_0$$

$$+ 4t_{1d}\left(\cos\frac{k_x}{2}\cos\frac{k_y}{2}\right)\sigma_z\tau_y\nu_0$$

$$+ t_c\sigma_0\tau_x\nu_x + t_c'\sigma_z\tau_y\nu_x .$$

$$E_{1,2} = 2t_0(\cos k_x + \cos k_y) \pm \sqrt{\left(t_c' + \varepsilon_{1d}(k_x k_y)\right)^2 + \left(t_c + \varepsilon'(k_x, k_y)\right)^2}$$

$$E_{3,4} = 2t_0(\cos k_x + \cos k_y) \pm \sqrt{\left(t_c' - \varepsilon_{1d}(k_x k_y)\right)^2 + \left(t_c + \varepsilon'(k_x, k_y)\right)^2}$$

$$E_{5,6} = 2t_0(\cos k_x + \cos k_y) \pm \sqrt{\quad + \qquad\qquad -}$$

$$E_{7,8} = 2t_0(\cos k_x + \cos k_y) \pm \sqrt{\quad - \qquad\qquad -}$$

$i\sigma_x\tau_x$ $-i\sigma_x\tau_x$

$G_x H(k_x, k_y)$

$\tau_x\tau_y\tau_x = i\tau_z\tau_x = -\tau_y$

HG_x

$i\sigma_x\sigma_z(-i\sigma_x) =$

$i(-i\sigma_y)(-i\sigma_x) = -i\sigma_y\sigma_x = (-\sigma_z)$

$(-\tau_y)$

$$G_x H(+k_x, k_y) G_x^{-1} = H(-k_x, k_y)$$

$$G_x H(-k_x, k_y) G_x^{-1} = H(k_x, k_y).$$

2016 / 9 / 20 (화) (4)

$$S_x H(-k_x, k_y) S_x^{-1} =$$

$$S_x = i\sigma_y \nu_x$$

$$i\sigma_y \sigma_z (-i\sigma_y) = -\sigma_x (-i\sigma_y) = i\sigma_x \sigma_y = -\sigma_z$$

M_z