

# ***Tight-binding models***

## **Hamiltonian I: Hydrogen chain**

Plot the band structure  $E(k)$  vs.  $k$  sites with the expected theoretical result  $E(k) = -2 \cos(k)$  plotted on top of it for comparison and the Fermi energy indicated with a horizontal line.



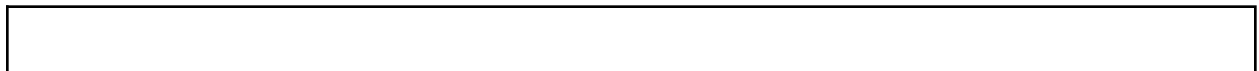
## **Hamiltonian II: Distorted hydrogen chain**

Plot the band structure ( $E(k)$  vs.  $k$ ) for the two bands. Indicate the Fermi energy with a horizontal line.



## **Hamiltonian III: graphene**

Plot  $E(k_x, k_y)$  vs.  $k_x, k_y$  on a  $27 \times 27$  lattice for the  $E > 0$  and  $E < 0$  bands. Make a 3d plot or a 2d plot that includes a point where the two bands touch at  $E = 0$ .



## **Hamiltonian IV: Boron nitride**

Plot  $E(k_x, k_y)$  vs.  $k_x, k_y$  on a  $27 \times 27$  lattice for the  $E > 0$  and  $E < 0$  bands. Make a 3d plot or many 2d plots (or both).



## **Hamiltonian V: Haldane honeycomb model**

For  $t' = 0.3$ ,  $\theta = 0.7$ ,  $M = 0.1$ , plot  $E(k_x, k_y)$  vs.  $k_x, k_y$  on a  $27 \times 27$  lattice for the  $E > 0$  and  $E < 0$  bands. Make a 3d plot or many 2d plots (or both).

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## ***Two forms of insulators***

For Hamiltonian  $V$ , plot the minimum gap between the two bands as you tune  $M$  from  $M=0$  to  $M=2$ . Do  $M=0, 0.8, 1.0, 1.2, 2.0$ . There is a transition when the gap becomes zero. At what  $M$  does this happen?

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Make contour plots of the berry curvature vs.  $(k_x, k_y)$  for  $M=0.8$  and  $M=1.2$ .

$M=0.8$	$M=1.2$
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Plot the Chern number vs.  $M$ . You should see it transition between 0 and 2 at the same  $M$  that the gap became zero.

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Make Hamiltonian  $V$  be periodic in the  $x$ -direction, but open in the  $y$ -direction. Plot  $E(k_x, y)$  versus  $k_x$  for each  $y$  on the same diagram. Make this plot with  $M=0.2$  (**left**) and  $M=2.0$  (**right**). You should see zero-energy edges modes at  $M=0.2$  and not at  $M=2.0$

$M=0.2$	$M=2.0$
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