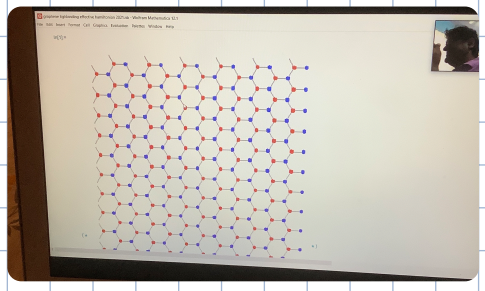
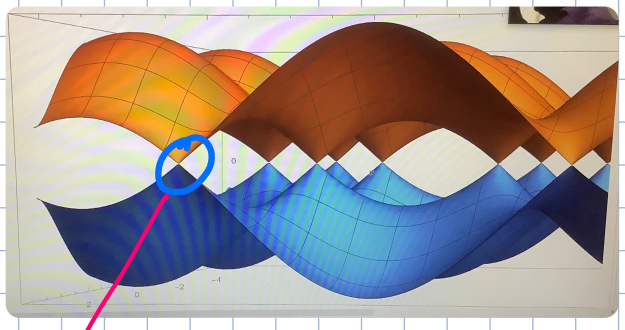
# Review of tBM from previous class

- SSH
- Graphene
- CuO

# Effective hamiltonian of Graphene near touching points.

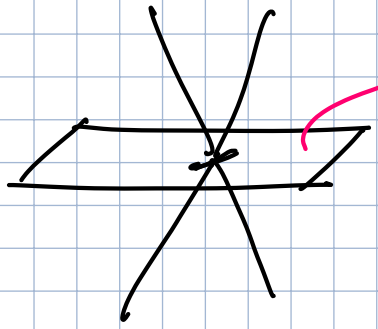




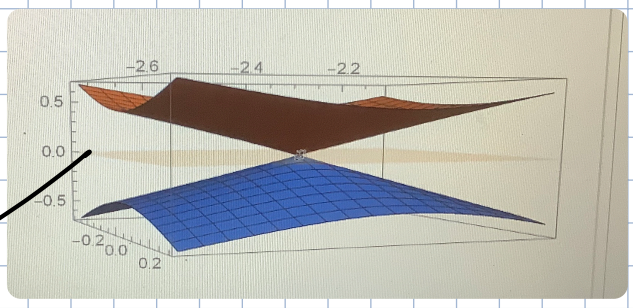
expand here

Semi-metal
↳ Low densities
↳ Gapless But only at precise points
⇒ metals have more k-space areas where its gapless.

→ p orbitals → unhyb 1e⊖
↓
½ filled
↳ states arise from hybridisation of these orbitals



→ due to 1e⊖ of p orbitals
⇒ ½ filling

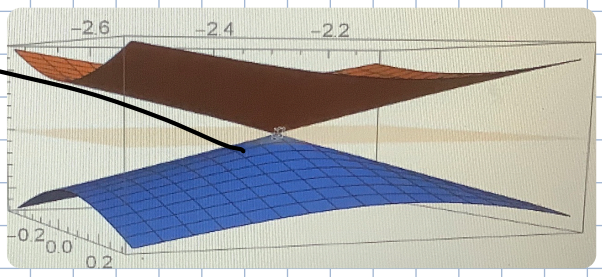



pristine graphene's fermi energy

# Taylor series expansion can be done in mathematica.

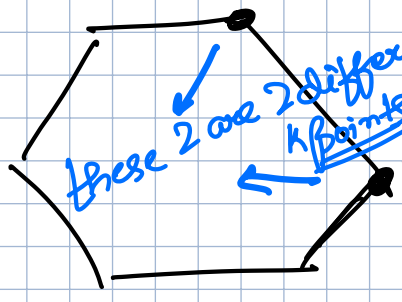
# Effective Hamiltonian :-

- Linear dispersion for low energy excitations




- $H = \begin{pmatrix} 0 & \frac{-3}{t}(2+\sqrt{3})\left(q_x - iq_y\right) \\ & 6 \end{pmatrix}$

$H = \vec{\sigma}\cdot\vec{p}$ → dirac hamiltonian for massless particles.




→ expand here

→ expand here

2 distincts K pnts

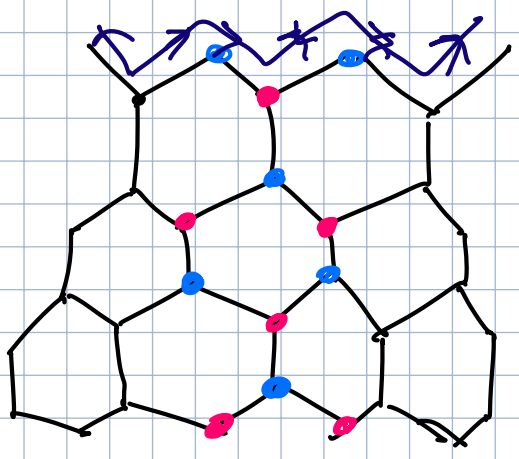
K  K' (valleys)

like A & B points in real space.

→ Structure of hamiltonian is different at these K pnts.

## Analogue of Gating for graphene

# Let's consider a GNR.



Q. What are the electronic states present in GNR?

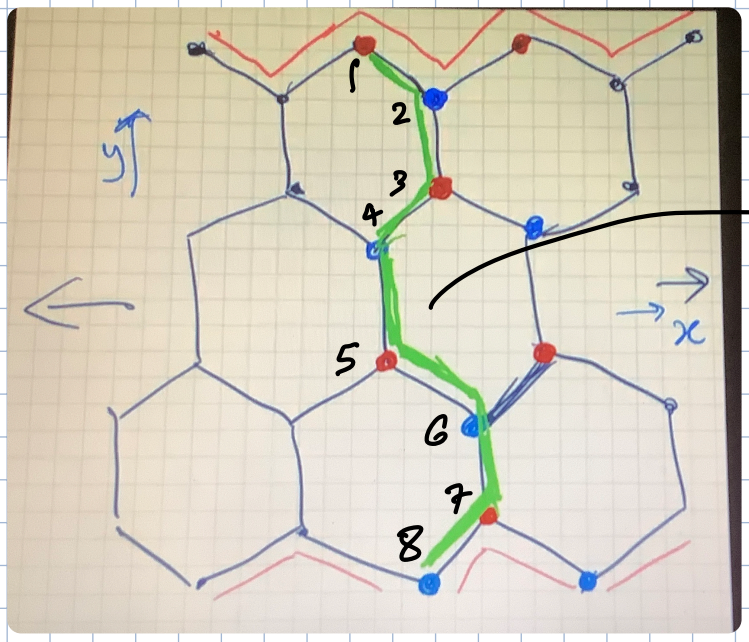
Motivat$^n$ :- from QHall, we know that edge states can be chiral & be ballistic.

We wanna see if something similar is

possible in Graphene.

# How do we do it?

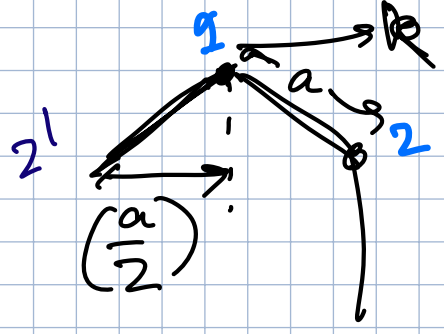
Brute force:- Define a Gigantic Unit cell.




Because y-directional translation symmetry is absent.

→ Call this a molecule

Now make a hopping matrix.

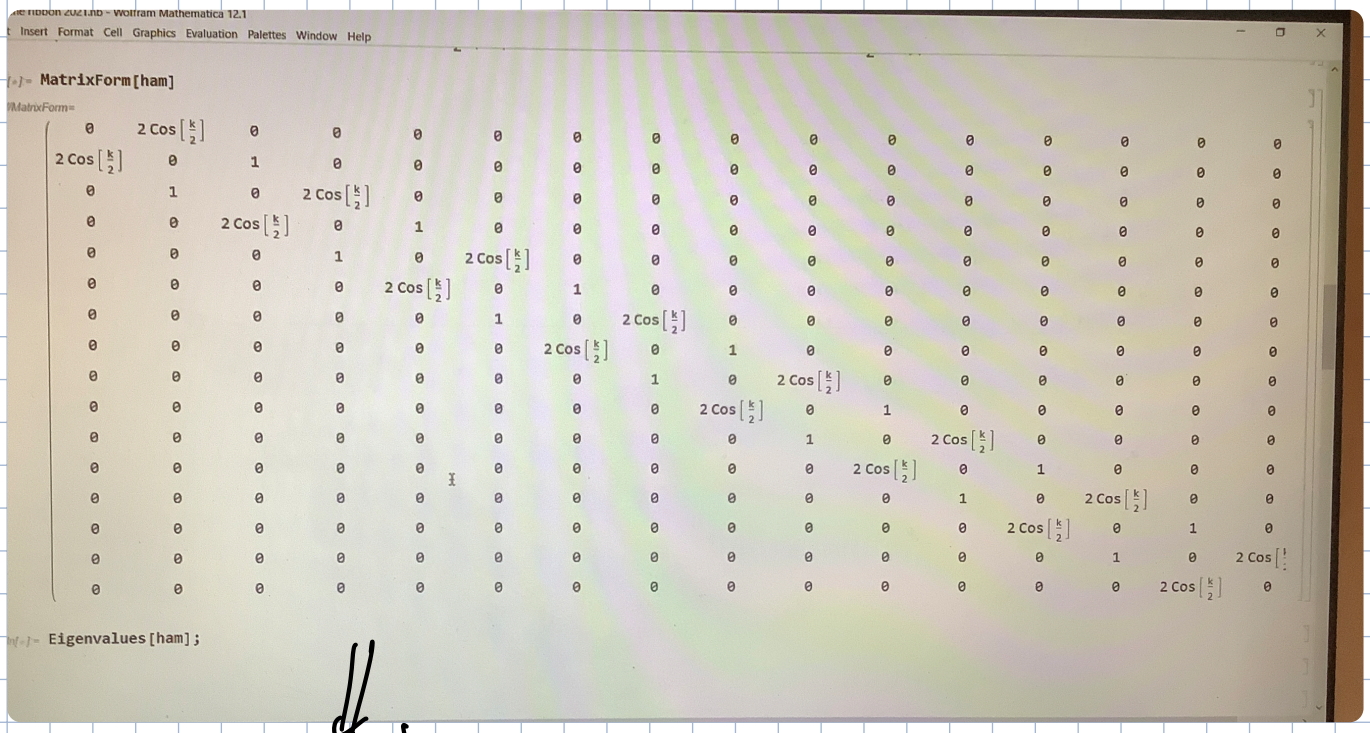



$te^{-ikx_0} + te^{-ik\frac{a}{2}}$ → Me

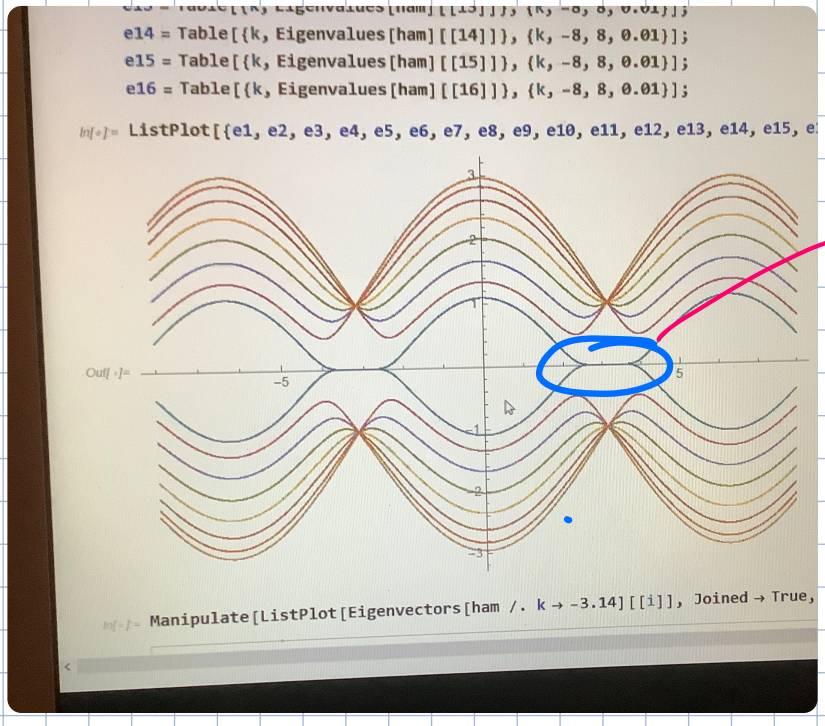
Disagreement:-

$te^{-ik\frac{a}{2}} + te^{+ik\frac{a}{2}}$ → MD

he's considering intracell non-trivial contributions as well




// we'll get 16 bonds

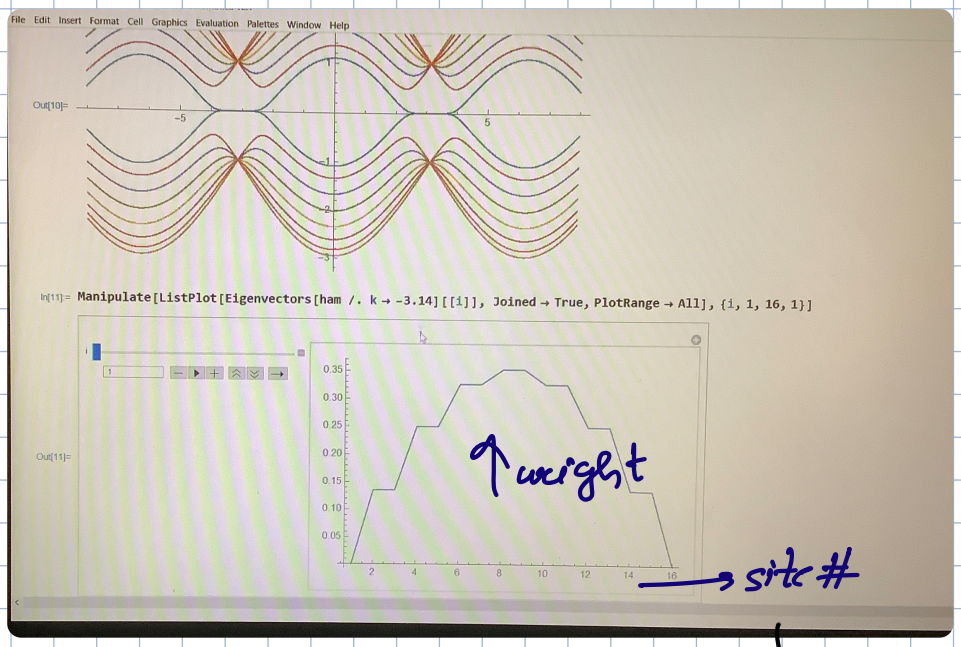



→ $k=\pi$, bonds are flat

↓ looks like $v_g = 0$, doesn't disperse.

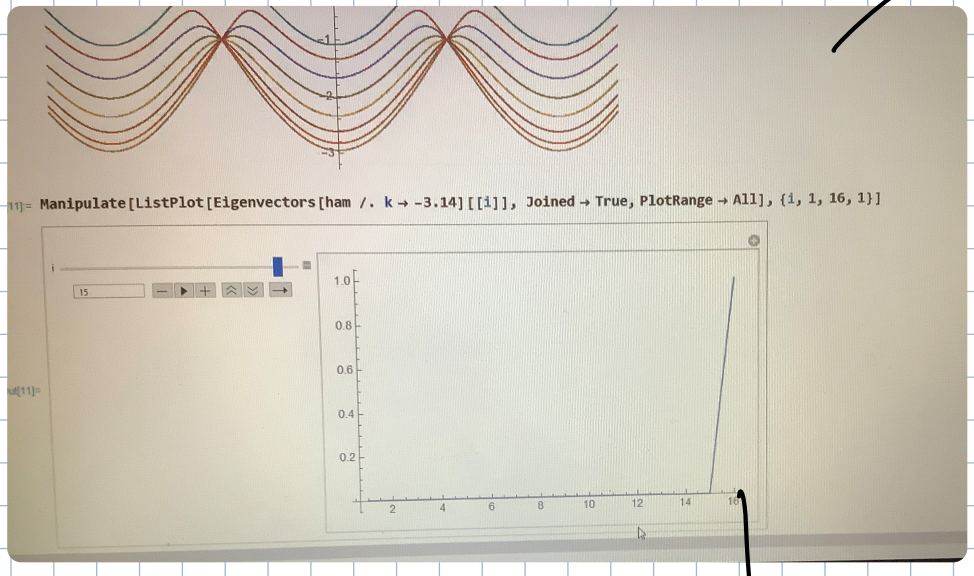
# now look at eigenvectors :-

→ amplitude ~ weight on a particular site.

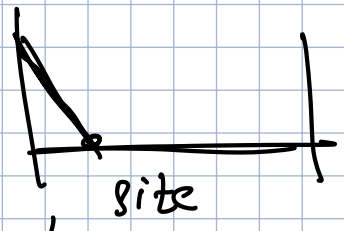



Behold the edge state :-

at k = -3.14



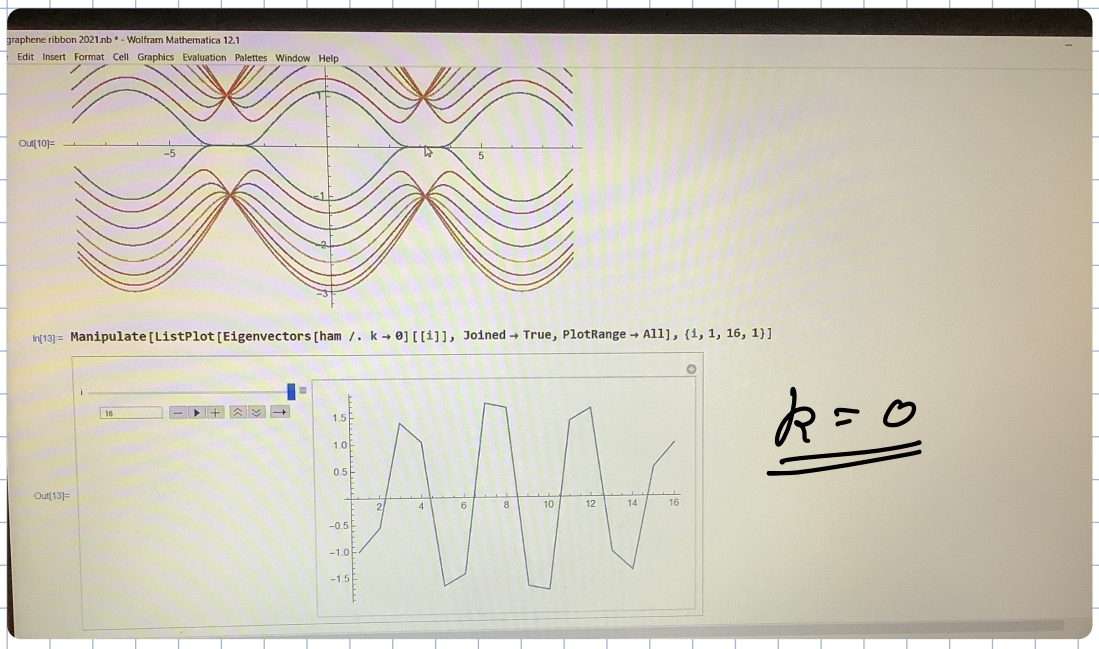

Similarly




$v_g = 0$, so they're stuck.

- eigenvectors reveal such features → reveal the effect of boundary conditions

At k = 0, it's different :-




k = 0

H.W :- Do this for Armchair GNR