Outline :-

MD → does 2D systems Berry curvature

Topological aspects of quantum matter

February 2021

Goal – to become very familiar about the consequences of effect Berry curvature / phase in electronic bands. To do calculations of toy models and understanding + explaining experiments.

solve problems in Mathematica quite intensively.

Approach – this subject is at the cutting edge of solid state physics and be taught in many ways. I will use an approach that goes beyond my area of research but will be centred around experiments.

our perspective will be expt

Books:

1. Supriyo Datta "Electronic Transport in Mesoscopic Systems" -- quantum Hall and mesoscopic physics Q. Hall
2. Shun-Qing Shen "Topological Insulators – Dirac equation in condensed matters"
3. David Vanderbilt "Berry Phases in Electronic structure theory"
4. Andrei Bernevig and Taylor Hughes "Topological insulators and topological superconductors"
5. Dan Ralph notes : arXiv:2001.04797 https://arxiv.org/abs/2001.04797

Other books:

1. Steve Girvin and Kun Yang "Modern Condensed Matter Physics" /alt to A&M
2. Harald Ibach and Hans Luth "Solid-state Physics"

Grading

we'll pay more attention to expt details.

2. Shun-Qing Shen "Topological Insulators – Dirac equation in condensed matters"
3. David Vanderbilt "Berry Phases in Electronic structure theory"
4. Andrei Bernevig and Taylor Hughes "Topological insulators and topological superconductors"
5. Dan Ralph notes : arXiv:2001.04797 https://arxiv.org/abs/2001.04797

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Grading

1. Roughly 60 % of the grade from 6-7 home works
2. Exam and term paper remaining 40%; depends on interest of the participants

this is where learning shall happen

around 12/13 lectures

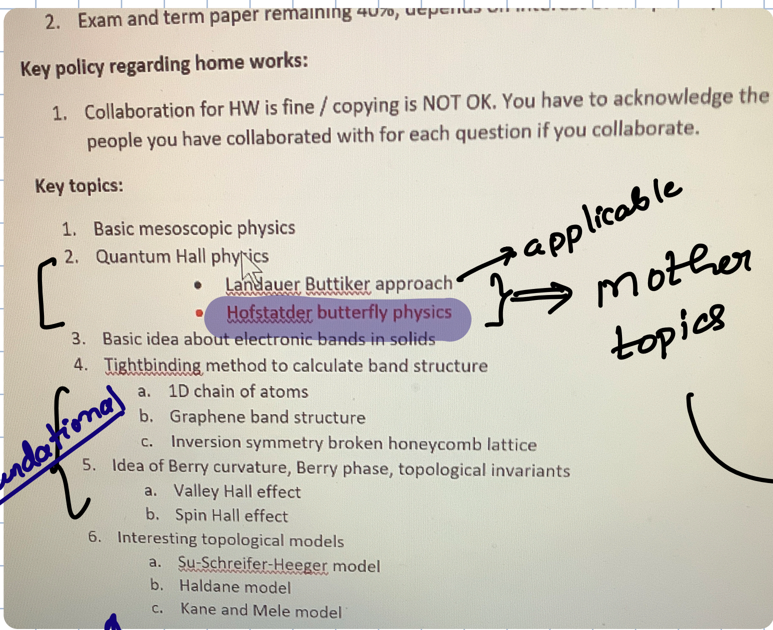
Key policy regarding home works:

1. Collaboration for HW is fine / copying is NOT OK. You have to acknowledge the names of people you have collaborated with for each question if you collaborate.

Key topics:

1. Basic mesoscopic physics
2. Quantum Hall physics
   - Landauer Buttiker approach
   - Hofstatder butterfly physics
3. Basic idea about electronic bands in solids
4. Tightbinding method to calculate band structure

English (India)

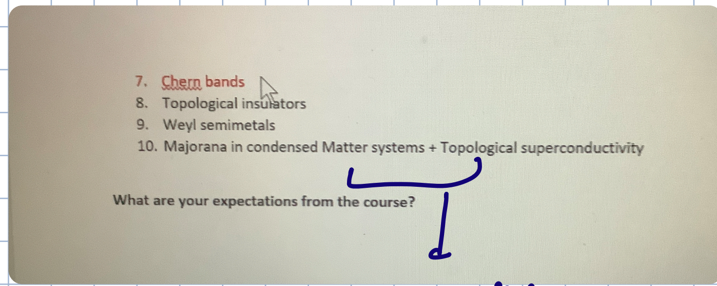


→ applicable

→ mother topics

foundational

maybe 1 or 2 will be added



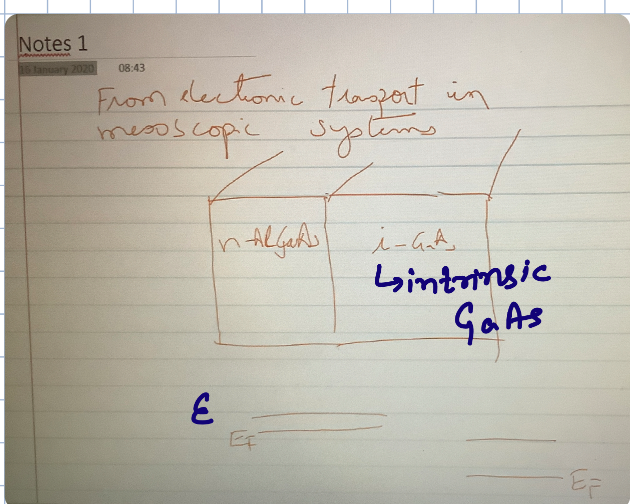
now we're talking

→ fractional quantum hall

Lecture 1

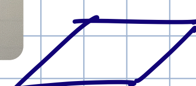
Main focus: Reduced dim & mesoscopic physics

From electronic transport in mesoscopic systems

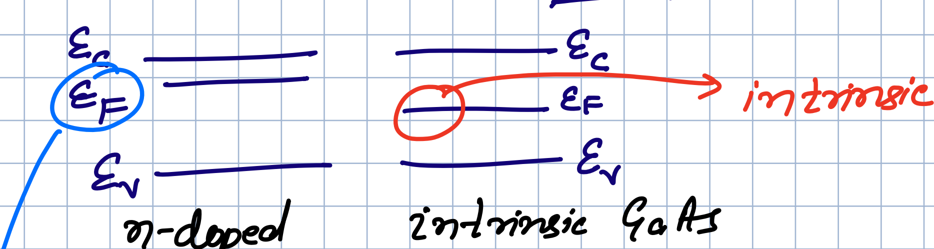


Oftentimes we need 2D system

marvel of semicond technology

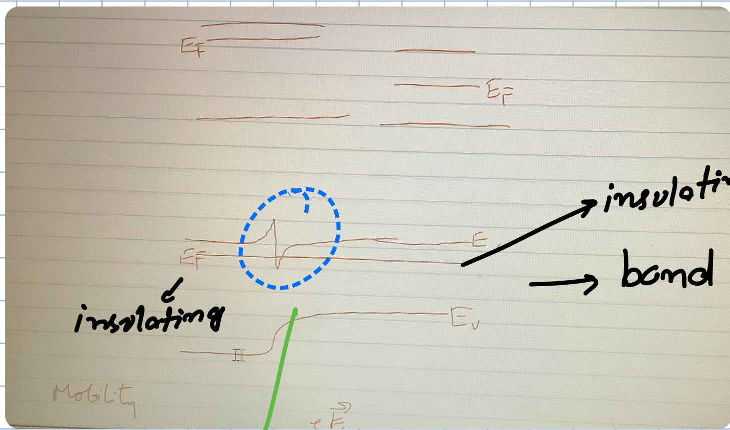


in layers → electrons move in layers like pages of a magazine



n-doped

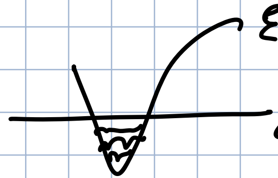
What happens if we bring an n-doped GaAs & i-GaAs together?



insulating

insulating → self consistent soln of poisson eqn

→ band bending



$\mathcal{E}_c$

$\mathcal{E}_F$

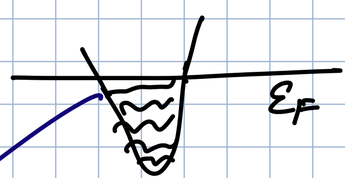
→ Electrons are trapped in 3rd dimension (say 2-dimension)

now this is suppressed.

now the system behaves like a 2D system.

"confinement in 1d"

} ⇒ now we can do Q. hall physics here



$\mathcal{E}_F$

world of 2D e^-'s

similarly (loosely) situations are possible for Topological insulators

Surface
- → gapless
- → free moving
- → topological

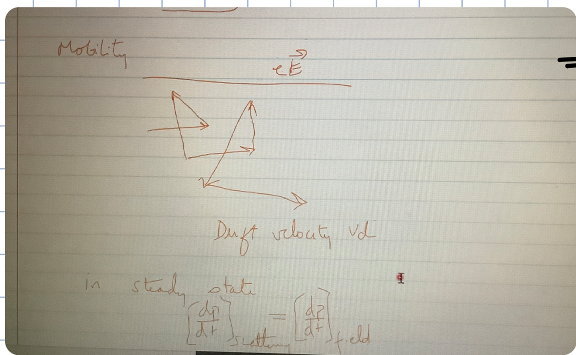
Bulk
- → Gapped
- → bloch like

Big point :- new physics can be explored using ingenious engineering.

⇒ 2DEG is key to realising topological materials

1DEG → realisable, if confine in one more direction

How does electron moves? ⇒ Drude model


Mobility

$e\vec{E}$

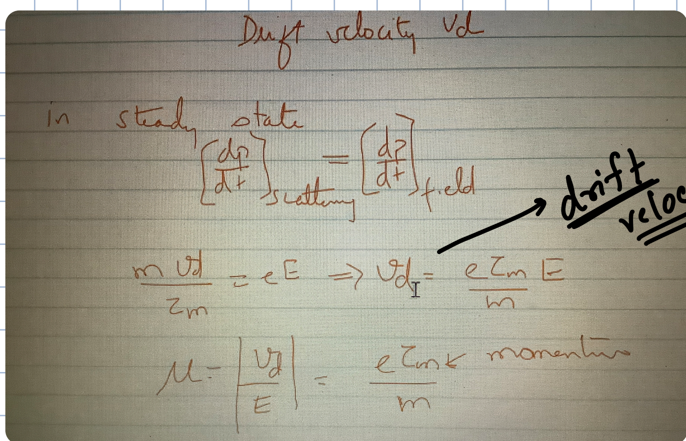
Drift velocity v_d

in steady state $\left[\frac{dp}{dt}\right]_{scattering} = \left[\frac{dp}{dt}\right]_{field}$

→ Bad assumption

all electrons respond to electric Field ✗ wrong

right ⇒ only near fermi energy does interesting stuff happen.


Drift velocity v_d

in steady state $\left[\frac{dp}{dt}\right]_{scattering} = \left[\frac{dp}{dt}\right]_{field}$

$\frac{m v_d}{\tau_m} = eE \Rightarrow v_d = \frac{e\tau_m E}{m}$

$\mu = \left|\frac{v_d}{E}\right| = \frac{e\tau_m}{m}$ momentum

drift velocity

scattering
- → momentum relaxat^n time
- → elastic (doesn't change phase)

inelastic collisions

has some comp. that fluctuates in time.

Inelastic collision ⇒ scatterer has to be time dependent

big contributor

① "scattering due to phonons"

② "spin d.o.f"

spin can have dynamics of its own & cause scattering

c.f. magnons

→ reduces timescales where electrons are coherent

→ if inelastic scatt. length is small → coherence length ↓

electrons → electron waves ⇒ Gives quantized conductance

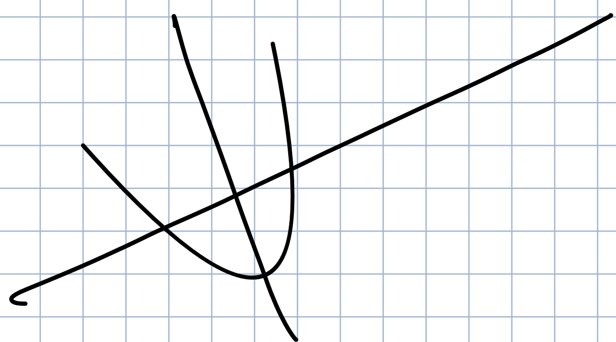
Quantized conductance paper.

→ more channels/modes → due to voltage

⇓

as we ↑ the gate voltage in +ve direct^n,

more modes pope in.



$$f = \frac{1}{e^{\beta(E-\mu)} + 1}$$