"Hall coefficient"

$$R_H = \frac{E_y}{j_x B} = \frac{-\frac{e\tau}{m} B\, E_x}{\left(\frac{ne^2\tau E_x}{m}\right) B}$$

I think we derived a few days ago, $j = \sigma E$

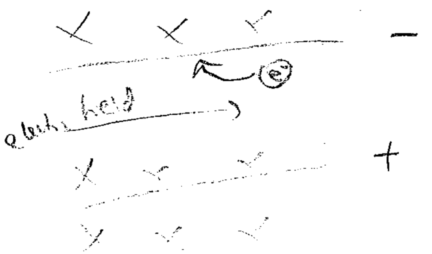
$$\boxed{R_H = -\frac{1}{ne}}$$

$\longrightarrow$ excellent way to measure n

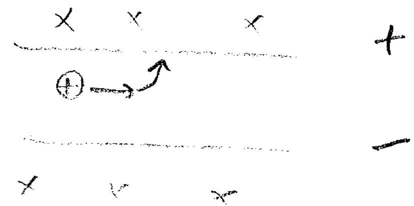
This model: n = atomic density x # valence electrons

Semiconductors n = # dopants

Cool: if electrons



if positive charges



also excellent way to measure sign of charge carrier.

Not always negative? No! "Holes"

Final thought:

since $\vec{J}$ and $\vec{E}$ are not parallel

$\vec{J} = \sigma \vec{E}$ doesn't work

need $\vec{J} = \overleftrightarrow{\sigma} \vec{E}$ ← rank 2 tensor!

$$\begin{pmatrix} \sigma_{xx} & \sigma_{xy} \\ & \text{etc} \end{pmatrix}$$

can have transverse conductivity $\neq$ long. conductivity

Crystal directions important; like our stiffness tensor get some terms = 0 depending on symmetry of crystal.

(see Stokes Ch. 1)

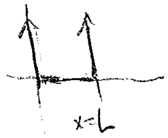
End of Ch 6

$\boxed{\text{Chap. 7: Band Theory!}}$

QM review

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + U(x)\psi = E\psi$$

Inf square well

$U(x) =$  then $\psi_n = A\sin\frac{n\pi x}{L}$ ~~$E_n = \frac{n^2\pi^2}{}$~~

$x=L$

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} = E\psi$$ only $0<x<L$

$\rightarrow 0$ at bndy $\rightarrow \sin\frac{n\pi x}{L}$

sin's + cosines

$$-\frac{\hbar^2}{2m}\left(-\frac{n^2\pi^2}{L^2}\right)\psi = E\psi$$

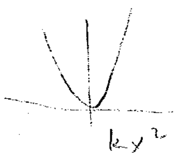
$$\boxed{E_n = \frac{n^2\pi^2\hbar^2}{2mL^2}}$$

→ In general!

$\psi = \sum C_n\psi_n$

$\psi \rightarrow \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_\infty \end{pmatrix}$

SHO

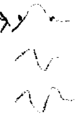
$U(x) =$  then $\psi_n =$ cosh?

kx^2

$E_n = (n+\frac{1}{2})\hbar\omega_0$

$\omega_0 = \sqrt{\frac{k}{m}}$

exponential decay when $E <$ barrier U?



"Matrix Elements" $\begin{pmatrix} \\ \\ \end{pmatrix}\begin{pmatrix} c_1 \\ \vdots \\ c_\infty \end{pmatrix} = E\begin{pmatrix} c_1 \\ \vdots \\ c_\infty \end{pmatrix}$

$\langle\psi_n|A|\psi_m\rangle$ called that even when no matrices in picture!

eigenvalue eqn!

or $i\hbar\frac{\partial}{\partial t}$?

$\int\psi_n^*\left(-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x)\right)\psi_m\,dx$

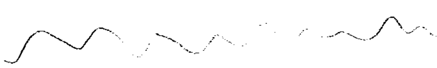
Discrete energy levels - characteristic of bound states

free particle: Doesn't always happen. For example

$U(x) =$ ——— (just 0)

then $-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} = E\psi$ $\psi = A\cos(kx + \phi)$

$\psi = \tilde{A}e^{ikx}$



k could be anything!

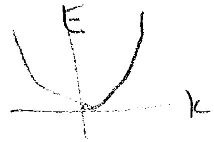
$-\frac{\hbar^2}{2m}(-k^2)\psi = E\psi$

$|\psi|^2 =$ constant

equally likely to find particle at all points in space!

$$\boxed{E = \frac{\hbar^2k^2}{2m}}$$ compare $E = \frac{p^2}{2m}$

$\hbar k =$ momentum of wave

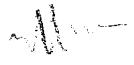


No discrete levels.

Energy "indexed" by k instead of by n

"Wave packets"

$\psi = \sum_k C_k\psi_k$

can get  for example

From 430 manual, Chapter 4

$$-\frac{1}{2}\frac{d^2\psi}{dx^2} + \frac{1}{2}x^2\psi = E\psi \quad \text{(harmonic oscillator)}$$

$$-\frac{1}{2}\left(\frac{f_{j+1} - 2f_j + f_{j-1}}{h^2}\right) + \frac{1}{2}x^2 f_j = E f_j$$

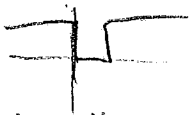
$$f_{j-1}\left(-\frac{1}{2h^2}\right) + f_j\left(\frac{1}{h^2} + \frac{1}{2}x^2\right) + f_{j+1}\left(-\frac{1}{2h^2}\right) = E f_j$$

$$\boxed{2^{\text{nd}} \text{ derivative: } \frac{\frac{f_{j+1} - f_j}{h} - \frac{f_j - f_{j-1}}{h}}{h}}$$

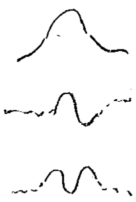
$$\begin{pmatrix} & & \\ -\frac{1}{2h^2} & \frac{1}{h^2} + \frac{1}{2}x^2 & -\frac{1}{2h^2} \\ & & \end{pmatrix}\begin{pmatrix} f_1 \\ \vdots \\ f_N \end{pmatrix} = E\begin{pmatrix} 1 & & \\ & 1 & \\ & & 1 \end{pmatrix}\begin{pmatrix} f_1 \\ \vdots \\ f_N \end{pmatrix}$$

1st + last rows = bndy conds

QM review, cont.

$U(x) =$ 

finite well

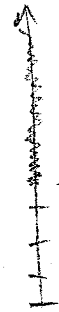


Numerical plots

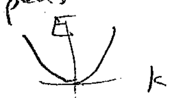
but a finite # of bound states

⇒ but still infinite # of unbound states when energy is high enough

E



← at some point



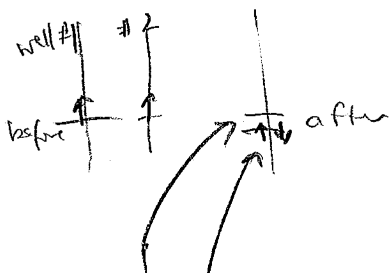
(perhaps)

$U(x) =$ 

Numerical plots?

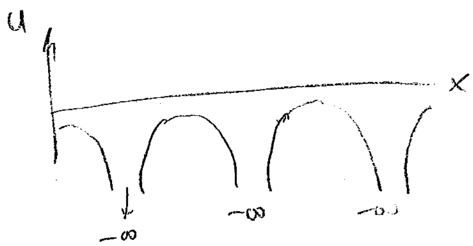
↳ compared to single well

lowest E



plots of eigenfunctions?

→ spreading out can lower energy!



Many

wavefunction of lowest state → energy = reduced!