621 MANY BODY PHYSICS II

Meets Weds 12:10 - 1:30 Serin 287
Fri 2 - 3:20 "

Extra Class Monday? WHAT TIME?

· First class Jan 19th
· Week of Jan 24th — No classes

Special Challenge! Intro to 620 was not held in Fall 2021.
Class with a broad range of backgrounds.

Purpose of today: to discuss the scope of the course
to arrange catch-up sessions for those who need them.
Many Body Physics: What is it?

Mathematical machinery for studying the EMERGENT PHYSICS of macroscopically large ensembles of particles. Modern context (outside astrophysics) involves Quantum Mechanics. The field exists at the intersection of Statistical + Quantum Mechanics, Quantum Field Theory, Condensed Matter Physics + Cold Atoms.

Our Goals This Semester

- Finite temperature, imaginary time + response functions
- Transport theory \( V=IR \)
- Broken symmetry + Ginzburg Landau
- Path integrals
- Superconductivity
- Heavy Fermion Physics
\( \Delta \) Introductions In Class

\( \Delta \) Many Particles + Second Quantization

\( \Delta \) Why Imaginary Time?

\( \Delta \) Path Integrals: What + Why?

\( \Delta \) What is a Superconductor?
Many Particles + Second Quantization

Why Imaginary Time? ✓

Path Integrals: What + Why? ✓

What is a Superconductor?

Many Particles + 2nd Quantization
\[ Z = \sum e^{-\beta (E_j - \mu N_\sigma)} = \int e^{-S[\psi, \bar{\psi}]} \text{ configs in space time} \]

Path integrals

"Coherent states"
Eigenstates of field operator

\[ \hat{\Psi}(x | \psi > = \psi(x) | \bar{\psi} > \]
\[
\langle \hat{\psi}(x) \rangle = \psi(x) \quad \text{- Dramatic Manifestation of Fock Space}
\]

\[
\langle N | \psi_y^+ \psi_x (N) = g(y, x) \rightarrow \psi_y^* \psi_x (x)
\]

\[
\hat{\phi}(x) = \sum_{j=1}^{N} \delta^3(x - x_j) \langle \hat{\phi} | \rangle = |\Psi| \rightarrow \hat{\phi}_{ij} \psi^+_y \psi_x (x)
\]

2nd Quantization

Many particles

\[
\psi(1, 2, \ldots, N, t) = (\pm 1)^0 \psi(p_1, p_2, \ldots, p_N, t)
\]

One particle

\[
\Psi(x, t) \quad P(x, t) = \mid \Psi \mid^2
\]

\[
\begin{array}{c}
\text{Li} \quad \text{Fe} \\
\text{H} \quad \text{Cu}
\end{array}
\]
What is Imaginary Time

Schrödinger Wavefunction:

\[ \psi(x_1, \ldots, x_n) = \langle x_1, x_2, \ldots, x_n \mid \psi \rangle \]

\[ \partial_t \mid \psi \rangle = \hat{H} \mid \psi \rangle \Rightarrow \mid \psi(t) \rangle = e^{-\frac{i \hat{H} t}{\hbar}} \mid \psi(0) \rangle \]

Schrödinger Equation

\[ Z = \sum e^{-\beta(E_j - \mu \nu_j)} = e^{-\beta E[T]} \]

\[ = \sum \langle j \mid e^{-\beta(\hat{H} - \mu N)} \mid j \rangle = \text{Tr} e^{-\beta \hat{H}} \]

\[ \sum_j \mid j \rangle \langle j \mid = 1 \quad \text{(Completeness)} \]

\[ e^{-\frac{\hat{H}}{k_B T}} \leftrightarrow e^{-\frac{i \hbar}{\tau}} \quad E_k \rightarrow e_k = (E_k - \mu) \]

\[ Z = \text{Tr} \left[ e^{-\frac{\hat{H}}{k_B T}} \right] \Rightarrow \text{All of Schrödinger} \]
\[ t = \left( \frac{\hbar}{k_B T} \right) x - i \hat{T}_p \]

\[ T_{\text{Planck}} = \frac{\hbar}{k_B T} \]

\[ Z = \text{Tr} \left[ U(-i T_{\text{Planck}}) \right] \]

- Imaginary time QM

- Correlations in imaginary time:
  \[ \langle A(t) A(0) \rangle \]
  \[ -i \langle [A(t), A(0)] \rangle = \Omega(t) \]
  \[ \langle A(t) \rangle = \int \Omega(t-t') B(t') \]

- Fluctuations

- Dissipation response in real time.
Subsystem or definite $m$

\[ \text{Tr} [e^{-\beta (\hat{\mathbf{h}} - \mu \hat{N})}] \]

\[ \sum_{N_0} \left( \text{Tr} \left( e^{-\beta \hat{h}_N} \right) e^{\beta \mu N_0} \right) \]