Physics 137B Lecture (Not sure)

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These are notes taken from lectures on Quantum Mechanics delivered by Professor Raúl A. Briceño for UC Berekley's Physics 137B class in the Sprng 2024 semester.

Contents

1 March 4 - Applications of the Fermi Gas Model

1.1 Recap - Fermi Gas Model

- Last time, we began studying the Fermi Gas Model, which is the large N limit of a system comprised of N spin-1/2 fermions in a box.
- We calculated the number of states corresponding to each momentum k and then integrated over k space:

$$dn = 2\left(\frac{L}{2\pi}\right)^3 d\Omega\, k^2 dk$$

- We found the ***Fermi Energy,*** E_F and the ***Total Energy,*** F_T

$$E_T = N \cdot \frac{3}{2} E_F$$

where $E_f = \left(\rho 3\pi^2\right)^{2/3} \cdot \frac{\hbar^2}{2m}$

- Notably, however, we only considered the system at $T = 0K$.
- The Fermi surface is the surface which bounds the sphere in n-space [Write better explanation later]

1.2 Finite Temperature

- At $T = 0K$, the system collapses to the ground state.
- At $T > 0K$, particles have enough energy to jump up to higher energy levels aka. jump the Fermo Surface. We find that

$$\langle n(E)\rangle = \frac{1}{\exp\left[\frac{E-E_F}{T}\right] - 1}$$

- Finite Temperature stuff is beyond the scope of this course, however, so we'll stick to the $T = 0K$ case.

1.3 Application - Stellar Evolution

- In the early stages, stars are mainly composed of Hydrogen.
- The thing that drives energy production in the stars is nuclear fusion, and the primary reaction that takes place is

$$\begin{aligned}
&p + p \to \underbrace{d}_{n,p} + e^+ + \overline{\nu}_e \\
&d + p \to He_3 + \gamma \\
&He_3 + He_3 \to p + p + He_4 \\
&\vdots
\end{aligned}$$

- What keeps the Star stable is the gravitational pull due to the immense mass of the star, which conflicts with the radiation pressure due to the nuclear reactions.

- Eventually, however, run out of nuclear fuel and gravity wins out. At that point, depending on the size of the star, various things can happen.
- Stars with masses $M < M_{sun} \times 1.5$ can form *white dwarfs* $[e^-]$ when gravity wins out.
- For stars with masses much greater than the sun, it is more energetically neutral for the reaction $e^- + p \to n + \overline{\nu}_e$, hence they are called neutron stars.

1.4 White Dwarfs

We can crudely model white dwarfs are seas of Fermi Elections.

Energy of the system: $E_T = E_{kin} + E_{grav}$ where $E_{kin} = N\frac{3}{5}E_F$
Write rest of the notes from recording, just pay attention in class.