

# 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 Berkeley's Physics 137B class in the Spring 2024 semester.

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# 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**,  $E_T$

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

$$\text{where } E_F = (\rho 3\pi^2)^{2/3} \cdot \frac{\hbar^2}{2m}$$

- 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

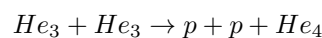
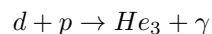
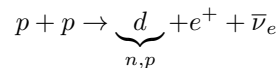
- At  $T = 0K$ , the system collapses to the ground state.
- At  $T > 0K$ , particles have enough energy to jump up to higher energy levels aka. jump the Fermi Surface. We find that

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

- 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



$\vdots$

- 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  $e^- + p \rightarrow n + \bar{\nu}_e$ , hence they are called neutron stars.

## 1.4 White Dwarfs

We can crudely model white dwarfs as seas of Fermi Electrons.

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.