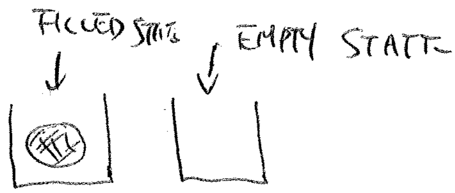
~~PARTITION FUNCTION~~ BOLTZMANN FACTOR

$$e^{-E/kT} = e^{-E\beta}$$

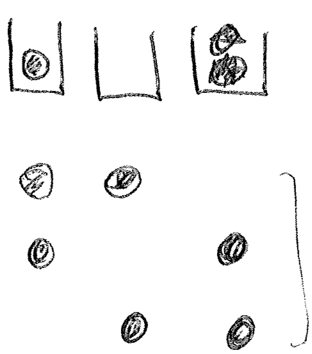
GIVEN $dS = \frac{1}{T}(dU + p\,dV - \mu\,dN)$

SIMILAR REASONING LEADS TO

$$e^{-(E-\mu N)\beta}$$ GIBBS FACTOR



- BOSONS CAN SHARE A STATE WITH OTHER ~~STATES~~ PARTICLES
- FERMIONS CANNOT SHARE A STATE WITH OTHER PARTICLES



MULTIPLICITY 9

FERMIONS $\underline{3}$

BOSONS $\underline{9}$

QUANTUM VOLUME

$$V_Q = \left(\frac{h}{\sqrt{2\pi m k T}} \right)^3$$: ~~DEI~~ WAVELENGTH OF PARTICLE CUBED

$kT = \frac{1}{40} eV = 0.025 eV = 1.6 \times 10^{-19} J \times 0.025 = 4 \times 10^{-21} J$

$m = 1.66 \times 10^{-27} kg \times 14/2 = 2.3 \times 10^{-26} kg \times 2$

$h = 6.626 \times 10^{-34}$

$\frac{h}{2\pi m k T} = \cancel{1.45 \times 10^{-11}}$ 1.9×10^{-11} m QUANTUM LENGTH

$V_Q = 7.3 \times 10^{-33} m^3$

look AT STP $= 22.4 l = 0.0224 m^3 = 2.24 \times 10^{-2} m^3$

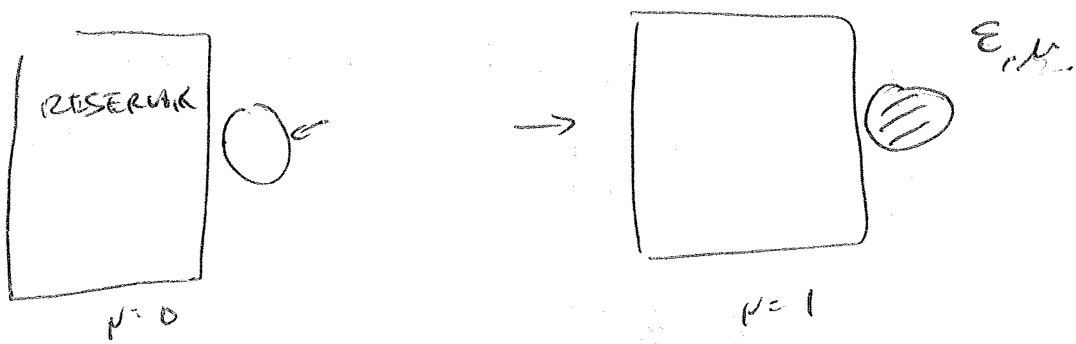
~~22400~~ $\frac{V}{N} = 3.7 \times 10^{-26} m^3$

$\frac{V}{N} >> V_Q$ DILUTE

SO BOSON + FERMIONS DON'T MATTER.

BUT IF IT GETS DENSE WHAT HAPPENS?

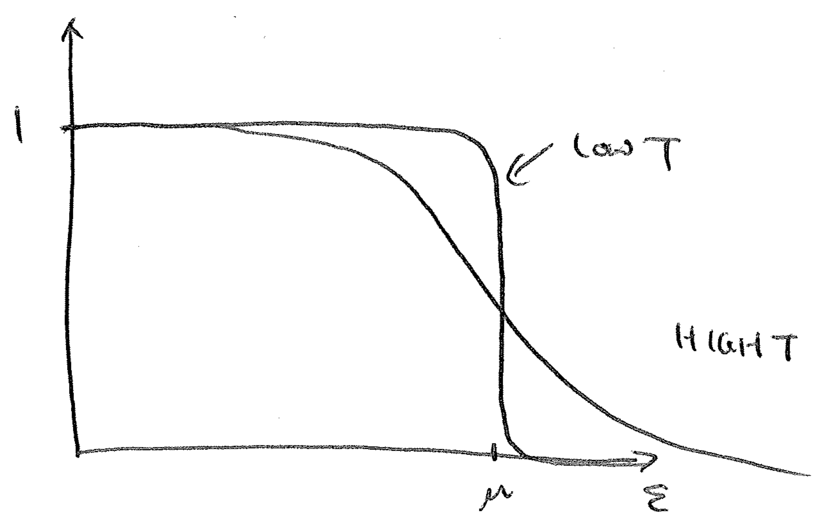
FERMI PARTICLES



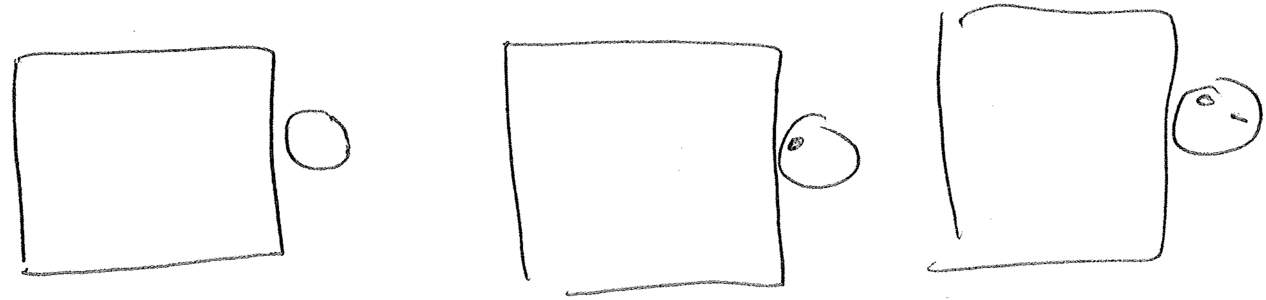
$$\mathcal{Z} = 1 + e^{-(\varepsilon-\mu)\beta}$$

$$P(\text{OCCUPIED}) = \frac{\cancel{e^{-(\varepsilon-\mu)\beta}}}{1 + \cancel{e^{-(\varepsilon-\mu)\beta}}} = \frac{1}{e^{(\varepsilon-\mu)\beta} + 1}$$

FERMI DISTRIBUTION



Bosons



$$\mathcal{Z} = 1 + e^{-(\varepsilon-\mu)\beta} + e^{-2(\varepsilon-\mu)\beta} + \cdots$$

$$= \frac{1}{1 - e^{-(\varepsilon-\mu)\beta}}$$

$$\langle n \rangle = \sum_n n P(n) = 0\,P(0) + 1\,P(1) + 2\,P(2) + \cdots$$

$$\langle n \rangle = \frac{1}{\mathcal{Z}} \sum_n n\, e^{-n(\varepsilon-\mu)\beta} = -\frac{1}{\mathcal{Z}}\frac{\partial \mathcal{Z}}{\partial x}$$

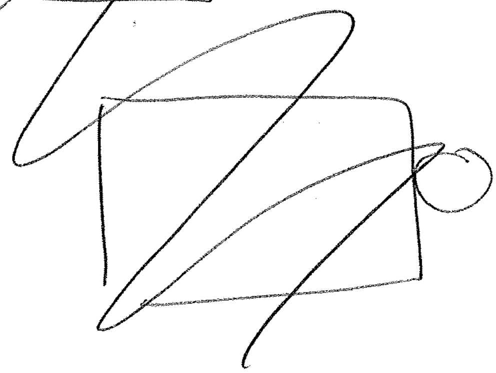
IF $(\varepsilon-\mu)\beta = x$

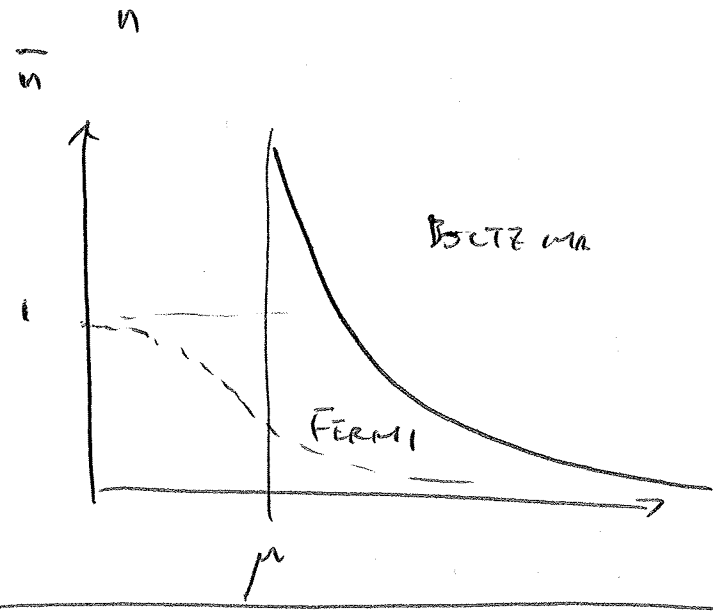
$\mathcal{Z} = (1-e^{-x})^{-1}$ so

$$\langle n \rangle = -\frac{-e^{-x}}{1-e^{-x}} = \frac{1}{e^{x}-1}$$

$$= \frac{1}{e^{(\varepsilon-\mu)\beta}-1}$$

~~BOLTZMANN?~~





μ FOR BOLTZMANN?

HOW DO THESE COMPARE TO BOLTZMANN STATISTIC?

μ? ~~[illegible]~~ μ $P(\text{OCCUPIED}) = \dfrac{e^{-\varepsilon/kT}}{Z}$

$$\bar{n} = \frac{N\, e^{-\varepsilon/kT}}{Z_1}$$

$$Z = \frac{Z_1^N}{N!} \qquad F = -kT \ln Z$$

$$= -kT\left[N \ln Z_1 - \ln N!\right]$$

$$= -kT\left[N \ln Z_1 - N \ln N + N\right]$$

$$F = -NkT\left[\ln \frac{Z_1}{N} + 1\right)$$

$$\frac{\partial F}{\partial N} = \mu = -kT\left[\ln \frac{Z_1}{N} + 1\right] - NkT\left(-\frac{1}{N}\right)$$

$$\mu = -kT \ln\left(\frac{Z_1}{N}\right)$$

$$-\frac{\mu}{kT} \qquad Z_1 = N e^{\mu/kT}$$

$$\bar{n} = e^{-(\varepsilon-\mu)/kT}$$