1 Paramagnet (multiple solutions)

We have the following equations of state for the *total magnetization* M, and the entropy S of a paramagnetic system:

$$M = N\mu \frac{e^{\frac{\mu B}{k_B T}} - e^{-\frac{\mu B}{k_B T}}}{e^{\frac{\mu B}{k_B T}} + e^{-\frac{\mu B}{k_B T}}} \tag{1}$$

$$S = N k_B \left\{ \ln 2 + \ln\left(e^{\frac{\mu B}{k_B T}} + e^{-\frac{\mu B}{k_B T}}\right) + \frac{\mu B}{k_B T} \frac{e^{\frac{\mu B}{k_B T}} - e^{-\frac{\mu B}{k_B T}}}{e^{\frac{\mu B}{k_B T}} + e^{-\frac{\mu B}{k_B T}}} \right\} \tag{2}$$

(a) Solve for the *magnetic susceptibility*, which is defined as:

$$\chi_B = \left(\frac{\partial M}{\partial B}\right)_T$$

(b) Use a chain-rule diagram to show there are enough constraining equations to find

$$\left(\frac{\partial M}{\partial B}\right)_S$$

(c) Find a closed form expression for

$$\left(\frac{\partial M}{\partial B}\right)_S.$$

Be ready for the possiblility that the final answer is zero (this might save you from writing out as much messy algebra).