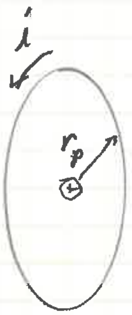
9.21) Treating the e^- and p^+ as classical particles orbiting each other, show the field seen by the e^- is

$$B = \frac{\mu_0}{4\pi}\frac{eL}{m_e r^3} \qquad (9.37)$$

b) Taking $L = 2\hbar$ (not $\sqrt{2}\hbar$) and $r = 4a_B$, show this gives $B \approx 0.39\,T$ and $\Delta E_{\text{up-down}} = 4.5\times10^{-5}\,eV$.

Apply the Biot-Savart law to the p^+ at the center of a current loop created by the e^-



$$dB = \frac{\mu_0}{4\pi}\left|\frac{i\,d\vec{l}\times\hat{r}}{r^2}\right| = \frac{\mu_0}{4\pi}\frac{i\,dl}{r_p^2} \qquad (\hat{r} \perp \text{ to } d\vec{l})$$

Integrating around the loop gives

$$B_{FS} = \frac{\mu_0 i}{\cancel{4\pi}_{\,2}}\left(\frac{\cancel{2\pi}\cancel{r_p}}{r_p^{\cancel{2}}}\right) = \frac{\mu_0 i}{2r_p}$$

The "current" of the e^- is

$$i = \frac{\text{charge}}{\text{time}} = \frac{e}{T} = \frac{ev}{2\pi r_p}$$

Taking the angular momentum of the (classical) e^- as

$$L = m_e v r_p \Rightarrow i = \frac{e}{2\pi r_p}\left(\frac{L}{m_e r_p}\right) = \frac{eL}{2\pi m_e r_p^2}$$

And

$$B_{FS} = \frac{\mu_0}{2r_p}\left(\frac{eL}{2\pi m_e r_p^2}\right) = \boxed{\frac{\mu_0}{4\pi}\frac{eL}{m_e r_p^3} = B_{FS}} \qquad (9.37)$$

$\hookrightarrow$ Magnetic field created by classical electron orbiting the proton which is the same as that experienced by the electron.