Box Num. 33
Problem Set 23
March 26, 2018

1. (a) The force on the electron in the electric field is given by $F_E = eE$, where e is the charge of the electron, and the time spent in the field is $t = \ell/v$. Therefore, the final y-velocity is

$$v_y = \frac{\ell}{v}\frac{eE}{m_e}$$

and so the final angle is

$$\theta_E = \arctan\left(\frac{\frac{\ell}{v}\frac{eE}{m_e}}{v}\right) = \arctan\left(\frac{\ell eE}{m_e v^2}\right)$$

(b) The force on the electron in this magnetic field is $F_B = qv \times B$. Because, for circular movement like this,

$$r = \frac{mv^2}{F} = \frac{mv}{eB},$$

Then, through setting up a system of similar triangles,

$$\theta_B = \arcsin\left(\frac{\ell eB}{mv}\right)$$

(c) Using the small-angle approximations for both tan and sin, when $\theta_B = \theta_E$,

$$\frac{\ell eE}{m_e v^2} \approx \frac{\ell eB}{m_e v} \implies E \approx vB$$

$$e = \frac{6\pi\eta r(v_1 + v_2)}{(1+n)E}$$

2. Let the electric field be given by $E = V/d$. Then, in the initial state, we have that

$$m_e g = Een \implies m_e = \frac{Een}{g}$$

where n is the number of electrons above neutral. Then, after it loses a single electron,

$$Ee(n+1) = 6\pi\eta r v_1 + m_e g$$

and finally,

$$m_e g = 6\pi\eta r v_2$$
$$Ee(n+1) = 6\pi\eta r(v_1 + v_2)$$

3. (a) This equation for force is identical to the one for a simple harmonic oscillator, so the angular frequency, ω, is just

$$\omega = \sqrt{k/m} = \sqrt{\frac{e^2}{4\pi\epsilon_0 R^3 m_e}} = 4.125\,\mathrm{rad/s}$$

Then

$$\lambda = \frac{2\pi c}{\omega} = 4.57 \times 10^{-8}\,\mathrm{m} = 45.7\,\mathrm{nm}$$

This is very different from the strongest emission line in hydrogen.

(b) With sodium,

$$\omega = 6.59 \times 10^{15}\,\mathrm{rad/s}$$

and

$$\lambda = 2.86 \times 10^{-7}\,\mathrm{m} = 286\,\mathrm{nm}$$

This wavelength is also off from the actual value by a significant factor.