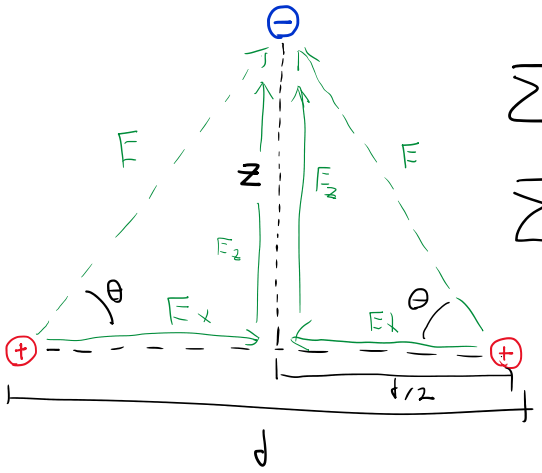
E1-1: E-Field Force

Monday, January 22, 2024 11:09 PM

An electron sits how distance z above two protons that are separated by some distance d. What is the force on the electron due to the magnetic field of the two protons?



$$\sum E_x = 0$$

$$\sum E_z = 2E_z = 2E\sin\theta\,\hat{k}$$

$$= 2\left(\frac{1}{4\pi\varepsilon_0}\frac{+e}{r^2}\sin\theta\right)\hat{k}$$

$$r^2 = \left(\frac{d}{2}\right)^2 + z^2$$

$$\sin\theta = \frac{z}{r} = \frac{z}{\sqrt{\left(\frac{d}{2}\right)^2 + z^2}}$$

$$E = \frac{+e}{2\pi\varepsilon_0}\frac{z}{\left(\left(d/2\right)^2 + z^2\right)^{3/2}}\hat{k}$$

Electric field due to the protons

$$F = qE \Rightarrow F = -e\left(\frac{+e}{2\pi\varepsilon_0}\frac{z}{\left(\left(d/2\right)^2 + z^2\right)^{3/2}}\right)\hat{k}$$

$$F = -\frac{e^2}{2\pi\varepsilon_0}\frac{z}{\left(\left(d/2\right)^2 + z^2\right)^{3/2}}\hat{k}$$

Force on electron due to E-field

If $d = 1$ mm & $z = 1$ cm, the magnitude of the force is

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$$d = 10^{-3}\ m \qquad z = 10^{-2}\ m$$

$$F = \frac{-e^2}{2\pi\varepsilon_0} \frac{10^{-2}\ m}{\left(\left(\frac{10^{-3}}{2} m\right)^2 + \left(10^{-2} m\right)^2\right)^{3/2}}$$

$$= \frac{-\left(1.602 \times 10^{-19} C\right)^2}{2\pi\left(8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2}\right)} \frac{10^{-2} m}{\left(\left(5 \times 10^{-4} m\right)^2 + \left(10^{-2} m\right)^2\right)^{3/2}}$$

$$= \frac{-\left(2.57 \times 10^{-38} C^2\right)}{\left(5.56 \times 10^{-11} \frac{C^2}{N \cdot m^2}\right)\left(1.0 \times 10^{-6} m^3\right)}$$

$$= -\frac{2.57}{5.56} \times 10^{-38} \times 10^{11} \times 10^{-2} \times 10^{6}\ N$$

$$\boxed{= -0.462 \times 10^{-23}\ N}$$