## 1. Problem 1

(a) For the ion to pass undeviated through the velocity selector, the force on the ion must be 0. So:

$$\begin{aligned} \vec{F} &= q(\vec{E} + \vec{v} \times \vec{B}) \\ 0 &= \vec{E} + \vec{v} \times \vec{B} \\ |v| &= \frac{|E|}{|B|} \end{aligned} \tag{1.1}$$

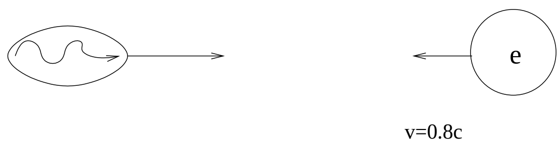
(b) After passing though the velocity selector the ions follow a circular path, so the magnetic force must provide the centripetal force:

$$\begin{aligned} q\vec{v} \times \vec{B}' &= -\frac{mv^2}{R}\hat{R} \\ qvB &= \frac{mv^2}{R} \\ \frac{q}{m} &= \frac{v}{RB} \\ &= \frac{E}{RBB'} \end{aligned} \tag{1.2}$$

## 2. Problem 2

(a)

Before:




After:

(b) This is a compton scattering problem. Energy and momentum are conserved, remember this is a relativistic process. Let $E_e$ and $p_e$ be the initial energy and the magnitude of the momentum of the electron and similarly $E$ and $p$ will be initial energy and magnitude of the momentum for the photon. Final quantities will be denoted with primes. We will take the right to be the positive direction.

$$\begin{gathered} E_e + E = E'_e + E' \\ \text{with} \\ E_e = \gamma mc^2 \qquad E'_e = \gamma' mc^2 \\ E = hf \qquad E' = hf' \end{gathered} \tag{2.1}$$

$$\begin{gathered} p - p_e = p'_e - p' \\ \text{with} \\ p_e = \gamma mv \qquad p'_e = \gamma' mv' \\ p = \frac{E}{c} \qquad p' = \frac{E'}{c} \end{gathered} \tag{2.2}$$

(c) We want the wavelength of the incoming photon, so we need to find $E$ or $p$. Solving (2.2) for $p'$ we find:

$$p' = \gamma mv + \gamma' mv' - p \tag{2.3}$$

So $E'$ is given by:

$$\begin{aligned} E' = cp' &= \gamma mvc + \gamma' mv'c - cp \\ &= (\gamma v + \gamma' v')mc - E \end{aligned} \tag{2.4}$$

plugging back into (2.1) gives:

$$
\begin{aligned}
E + E_e &= E' + E'_e \\
E + \gamma mc^2 &= (\gamma v + \gamma' v')mc - E + \gamma' mc^2 \\
E &= \tfrac{1}{2}((\gamma v + \gamma' v')mc - (\gamma - \gamma')mc^2) \\
&= \frac{10}{12}mc^2 \\
\frac{10}{12}mc^2 &= hf \\
&= h\frac{c}{\lambda} \\
\lambda &= \frac{12}{10}\frac{h}{mc} \\
&= 2.9 \times 10^{-12}m
\end{aligned}
\tag{2.5}
$$