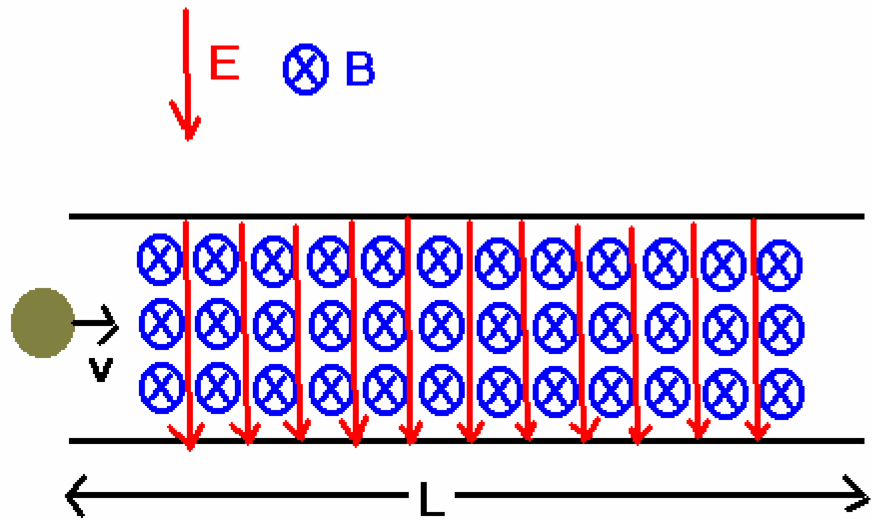
Motion of a charged particle in a combined electric and magnetic field. Explain how a *velocity selector* and a Mass spectrometer works.

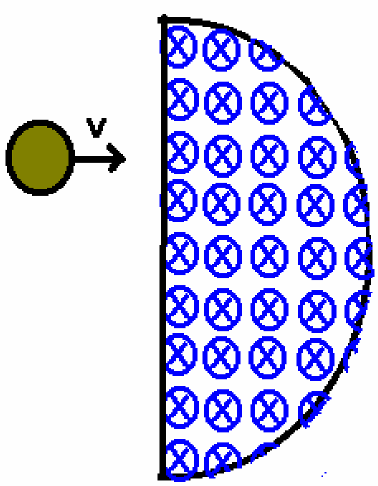


Consider the parallel plate capacitor shown. The electric field is directed downward while the magnetic field is directed into the figure as shown. Assume a positively charged particle of mass m is moving with a velocity v perpendicular to both B and E. The total force on the particle is given by

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Let v be along the x axis and then B is along the y axis. The particle will then experience an upward magnetic force (along the +z direction) given by qvB. On the other hand, the particle will experience a downward electrostatic force given by qE. If the two forces balance, then qvB=qE so that v=E/B. If you want to select a beam of particles with this velocity, then you adjust the ratio of E to B appropriately.

Now, how does a mass spectrometer work?



A positive particle of mass m is traveling with a velocity v and encounters the magnetic field. The particle then undergoes circular motion with the "centripetal" force given by the Lorentz force, F=qvB. Since this is uniform circular motion, the particle will orbit with a centripetal acceleration given by mv^2/R. So, the radius of orbit will be given by R=mv/qB. With a beam of particles all with the same velocity, when the particles strike the wall, they will deposit (piles) of increasing radii with increasing mass. This provides a very sensitive refining technique and also a very sensitive detection technique. Note that the magnetic work done on the charged particle is **zero!**