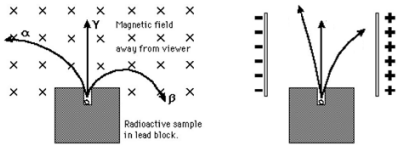
General Physics II Honors (PHYS 102H)

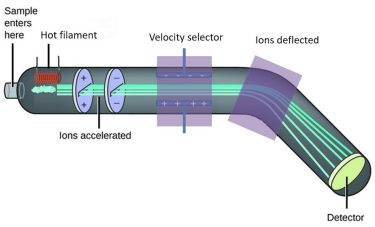
Problem set # 6 *(due March 29)*
All problems are mandatory, unless marked otherwise. Each problem is 10 points.

Q1 Let's travel back in time again, when Henri Becquerel accidentally discovered ionizing radiation experimenting with photosensitive materials. Since the nature of the emitted "rays" was completely unknown, he sent the output of the radioactive emitter through constant magnetic field and noted the three distinct behaviors, shown in the left image: some rays bent left, some right, some continued straight. He named them α, β and γ rays.



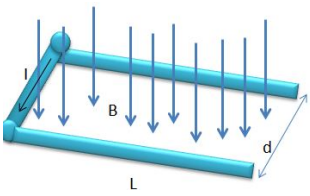
(a) Assuming you know how charges behave in the constant magnetic field, what information about these "rays" can you extract from this observation?
(b) Now the same radioactive source is placed in front of the capacitor, as shown in the right picture. Again, three distinct behaviors emerges. Label which track corresponds to which type of radiation.

Q2 Mass spectrometer is a common apparatus in many physics, material and chemistry labs and it allows determine chemical decomposition of materials by measuring masses of their components. A standard mass spectrometer consists of three main elements: ion accelerator, velocity selector, and magnetic deflector.



(a) Once the material is broken apart into ions, these ions are accelerated by travelling between two electrodes with voltage difference $V = 2$ kV. If an ion mass of a singly-charged uranium is $m = 4 \times 10^{-25}$ kg, what is the ion velocity after the accelerator if we assume that initially ions are at rest?
(b) Velocity selector consists of an electric field perpendicular to the ion track, and magnetic field (purple shaded area in the image) perpendicular to both ion velocity and electric field. The values of the electric and magnetic fields are tuned to allow only ions with specific velocity to move straight, so they can be later filtered by a small hole. If the electric field is created by the capacitor as shown, should the magnetic field be directed in or out of the page? Does the answer changes if the ion is positive or negative?
(c) If the magnitude of the electric field is $E = 2500$ V/m, and the magnetic field is $B = 0.035$ T, what velocity is selected?
(d) Finally, the ions with potentially different mass but same velocities enter the deflector, consisting of only magnetic field that is usually the same as in the velocity selector. Entering ions start moving along the circular path, radius of which depends on their mass. Assuming that two uranium isotopes have the mass difference of $m = 5 \times 10^{-27}$ kg, what is the difference between radii of their paths inside the deflector?

Q3 A rod of mass m rests of two parallel rails that are separated by distance d and have length L. The whole assembly is in magnetic field pointing vertically down. At $t = 0$ constant electric current I starts running through the rod, as shown.



(a) Describe how the rod starts moving.
(b) What is the speed of the rod as it leaves the rails?
We will actually revisit this problem next week to consider a more realistic scenario that includes magnetic induction.