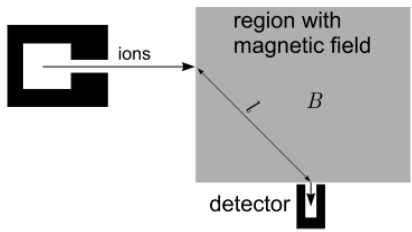
7. Mass-spectrometer (9 p)

In the figure below, a simplified scheme of a mass-spectrometer is given. It is a device for measuring the masses of molecules. The substance under investigation is ionised by heating up to a temperature T on a hot filament (molecules undergo a single-electron ionisation). The ions are accelerated using voltage U. At first, let us neglect the thermal energy of the ions ($eU \gg kT$, where e is elementary charge and k — the Boltzmann's constant). A narrow beam of accelerated ions enters a region with magnetic field. For the sake of simplicity, let us assume that the region has a rectangular shape, and the magnetic field is homogeneous inside it. The magnetic fields deflects the ions and depending on their mass, they may hit the detector. Let us assume that those ions which hit the centre of the detector enter and exit the region with magnetic field perpendicularly with its boundary, and the distance between the entry and exit points is l (see figure).



1) Express the mass M of those ions which hit the centre of the detector via the quantities B, l, U and e.

2) The entrance to the detector is a circle with radius r ($r \ll l$). Because of the finite size of the detector entrance, ions within a mass range from $M - \Delta M$ to $M + \Delta M$ will enter the detector; find the range width ΔM.

3) Under the assumptions of the previous question, what is the width of the range of the exit angles $\Delta\varphi$ of those ions which can still hit the detector?

4) Now let us assume that r is negligibly small, but we cannot neglect the thermal effects (still $eU \gg kT$). Due to difference in energies, the detector can be hit by ions of different masses, within the range from $M - \delta M$ to $M + \delta M$. What is the resolving power δM of the mass-spectrometer?