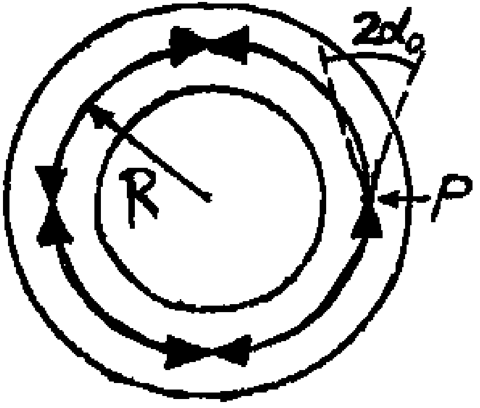
Problem 2: Electrons in a magnetic field

A beam of electrons emitted by a point source P enters the magnetic field $\vec{B}$ of a toroidal coil (toroid) in the direction of the lines of force. The angle of the aperture of the beam $2 \cdot \alpha_0$ is assumed to be small ($2 \cdot \alpha_0 \ll 1$). The injection of the electrons occurs on the mean radius R of the toroid with acceleration voltage V_0.

Neglect any interaction between the electrons. The magnitude of $\vec{B}$, B, is assumed to be constant.



1. To guide the electron in the toroidal field a homogeneous magnetic deflection field $\vec{B}_1$ is required. Calculate $\vec{B}_1$ for an electron moving on a circular orbit of radius R in the torus.

2. Determine the value of $\vec{B}$ which gives four focussing points separated by $\pi/2$ as indicated in the diagram.

   Note: When considering the electron paths you may disregard the curvature of the magnetic field.

3. The electron beam cannot stay in the toroid without a deflection field $\vec{B}_1$, but will leave it with a systematic motion (drift) perpendicular to the plane of the toroid.

   a) Show that the radial deviation of the electrons from the injection radius is finite.

   b) Determine the direction of the drift velocity.

   Note: The angle of aperture of the electron beam can be neglected. Use the laws of conservation of energy and of angular momentum.

Data:

$\frac{e}{m} = 1.76 \cdot 10^{11}\,\mathrm{C \cdot kg^{-1}}$; $V_0 = 3$ kV; R = 50 mm