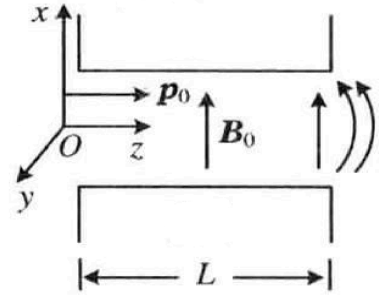


## APhO 2005 T2B: Magnetic lens (improved)

This is adapted from a Chinese textbook (物理学难题集萃, 舒幼生 et al.). The original APhO problem was worded really poorly and used some weird artificial assumptions that aren't really necessary or correct. Don't reference the original problem, as it will spoil some parts of the solution (even the title of the problem is a spoiler!). The difficulty of this problem is around a EuPhO T2.

Define a coordinate system as shown. We have two identical cuboidal permanent magnets with uniform magnetisation along the  $x$ -axis. The length of the magnets in the  $z$ -direction is  $L$ . The lengths of the magnets in the  $\pm x$  direction and  $\pm y$  direction are much larger than  $L$ . The magnets are placed with opposing poles close to each other (separation  $\ll L$ ) to create a magnetic field with magnitude  $B_0$  at the center of the cross-section.



A stream of charged particles, each with charge  $q$ , is ejected at  $y = z = 0$  at various positions along the  $x$ -axis. The particles each have an initial momentum of  $\mathbf{p}_0 = p_0 \hat{z}$ , where  $p_0 \gg qLB_0$ . Show that the charged particles are focussed to a point, and find the  $z$ -coordinate of this point.

Ignore mutual interactions between the charged particles. The particles are moving at a nonrelativistic speed.