3. A right circular cylinder of radius R and length L is carrying a uniform current I parallel to the axis of the cylinder.

a) What is the direction and magnitude of the magnetic field inside the cylinder? (Ignore end effects, and other sources of the B field).

b) Next, directed towards the above current-carrying cylinder and parallel to its axis is a parallel monochromatic beam of energetic charged particles. Show that within the following approximation the beam will be focused at a point after passing through the cylinder. Derive an expression for the focal length.

In the derivation neglect scattering and slowing down of the beam's particles due to interactions with the material within the cylinder (other than through the field described above), and make the thin lens approximation by: i) assuming that the cylinder is short compared to the focal length, yet at the same time, ii) ignoring end-effects.

c) Consider using the magnet to collect into a parallel beam antiprotons produced by a beam of high-energy protons that strike a target placed at the focal point of the magnetic lenss. Specifically: assume the magnet is a cylinder of lithium metal of length 15 cm and radius 1 cm, and the total current it carries is I. What current would be required to collect antiprotons that are produced with a momentum of 10 GeV/c at angles up to 50 mrad relative the beam axis?

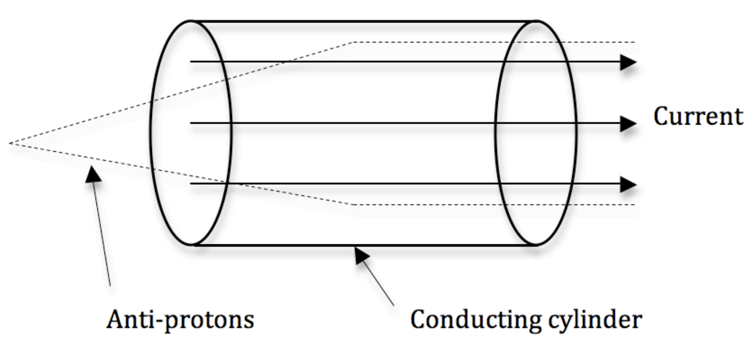

Fig. Ilustration for part c) (only)

Some useful constants, and magnitudes:
$\mu_0 = 4\pi \times 10^{-7}\, N\, A^{-2}$, $e = 1.60 \times 10^{-19}$ C, proton mass $m_P = 1.67 \times 10^{-27}$ kg.