

**PHYS2050 – Electromagnetism**  
**Session 2, 2009**

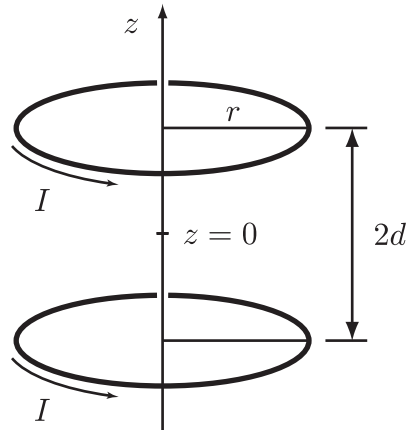
**Assignment 2**

Due: Friday 16 October 2009

**Question 1** (10 marks)

A wonderfully uniform magnetic field can be obtained inside an infinitely long solenoid. Unfortunately these are a little impractical in the laboratory. So instead we use a “**Helmholtz coil**” – an arrangement of two circular wires of radius  $r$  carrying equal currents as shown in the figure.

- (a) Find the field  $\mathbf{B}$  along the axis of the coils as function of  $z$ .
- (b) Show that the derivative  $\partial B/\partial z$  vanishes halfway between the coils, and hence that the field is uniform here.
- (c) Calculate the second derivative  $\partial^2 B/\partial z^2$  at the midpoint, and determine the geometry of the coils such that this vanishes. What is the final field at the origin?



**Question 2** (10 marks)

A neutral conducting sphere of radius  $R$  is pulled through a uniform magnetic field  $\mathbf{B} = B \hat{y}$  at a constant velocity  $\mathbf{v} = v \hat{x}$  (perpendicular to the field). This causes a separation of charges within the sphere (think of the Hall effect). Calculate the charge distribution.

Hints:

- (a) Start by considering the total force on a charged particle inside the sphere. This will allow you to derive the electric field inside the sphere. (In electrostatics,  $\mathbf{E} = 0$  inside a conductor, but now there is a magnetic field too!)
- (b) Use Example 3.8 in Section 3.3 of Griffiths textbook to guide your derivation of the charge density on the sphere.

**Question 3** (10 marks)

Warning: This question requires some knowledge of Special Relativity. Well, to be honest you pretty much need to know it by now, so go ahead and check the internet or a textbook. You will also need the identity  $\mu_0 \epsilon_0 = 1/c^2$ .

- (a) Consider two infinite parallel lines of charge with charge per unit length  $\lambda$  in their rest frame separated by a distance  $r$ . Calculate the force per unit length  $\mathbf{f}$  between the wires. Call this frame  $S$ .
- (b) Now consider a different frame, one moving along the lines of charge at speed  $v$ . In this frame,  $S'$ , there will also be a magnetic component since the lines of charge are now moving. Calculate the force per unit length  $\mathbf{f}'$  in  $S'$ .
- (c) Calculate the observed charge density  $\lambda'$  in terms of quantities in the frame  $S$  (unprimed quantities). Does  $\mathbf{f} = \mathbf{f}'$ ?
- (d) Explain (mathematically) why the force per unit length on the wires *should* be the same in  $S$  and  $S'$  (after all, forces do transform in special relativity).