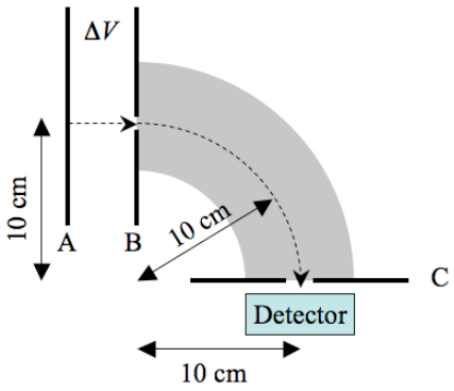
Physics 380-001: Chapter 5 Homework

1. Bendie (6 pts): A flexible wire which is partially stretched between the faces of a magnet with the field directed into the paper. What will happen to the wire when:

(a) There is no current in the wire.
(b) The current is pointing upwards.
(c) The current is pointing downwards.

2. The Mass Spectrometer (8 pts): Sodium ions (charge +e) are accelerated from rest at plate A through a voltage difference of ΔV = 1 kV to plate B. Some of the ions pass through a small slit in plate B to enter into a region of uniform magnetic field (the shaded region in the diagram).



(a) Which plate is at a higher potential, A or B? Calculate the speed of the Na+ ions when they reach the slit in plate B.
(b) When the ions enter the region of constant magnetic field, they experience a force that is perpendicular to their velocity. Using Newton's Laws, what must be the magnitude and direction of this force if these ions are to follow a curved path of radius r = 10 cm?
(c) Find the magnitude and direction of the magnetic field needed for the force you found in part (b).
(d) Suppose instead you started with magnesium ions at plate A, and accelerated them through the same potential difference ΔV. If you want the magnesium ions to reach the detector, should you move the slit in wall C to the left or to the right? By how much? (Think carefully about the geometry.)

3. Biot-Savart (12 pts): You have been asked to design a magnetic trap for your summer internship.

(a) First, consider a circular loop of wire of radius R located in the xz plane and carrying a steady current. Determine the magnetic field at an axial point P a distance x from the center of the loop. (Make sure to include a sketch.)

(b) But, one loop isn't going to get you enough B field strength, so you have to wrap 48 loops (8 layers of 6 windings). But since the loop is small, you need to consider the effects of the wire's size. The wires have a 2.4 mm outer diameter and a 1.2 mm inner diameter. The coil consists of an inner diameter of 10 mm and an outer diameter of 47 mm. Numerically (Excel is good) find and plot the magnetic field at an axial point P a distance x from the center of the loop. (I=100 Amps is reasonable)

(c) If another coil is placed 27 mm away and has opposite current. Plot the B field as a function of at an axial point P a distance x from the center of the loops.

(d) This is actually used, see http://george.ph.utexas.edu/papers/libson.Hyperfine.pdf

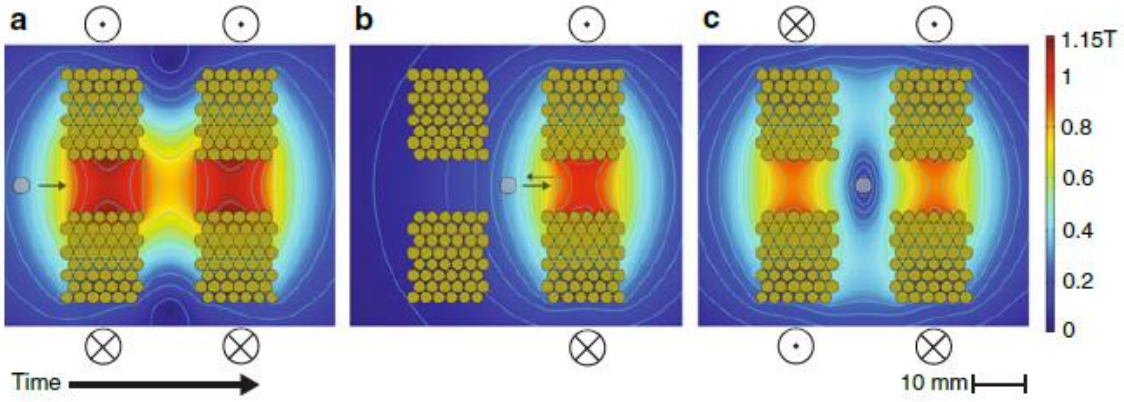
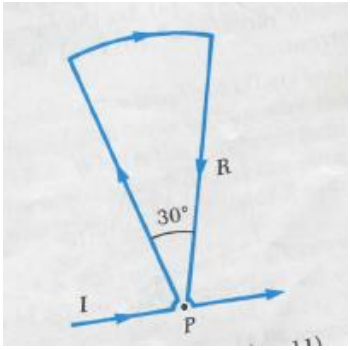


Fig. 2 Numerically calculated magnetic field profiles of the trapping coils at different stages of the trapping sequence. In **a** the cloud is approaching the trap from the coilgun and the front trap coil is used as a final slowing coil. The cloud then enters the trapping region and is stopped by the rear trapping coil as shown in **b**. Lastly, the front trapping coil is switched on, trapping the cloud in a 100 mK deep trap as illustrated in **c**

Figure taken from http://george.ph.utexas.edu/papers/libson.Hyperfine.pdf

4. Toroidal Coil (4 pts): The toroidal coil consists of N turns of wire wrapped around a doughnut-shaped structure. Assuming that the turns are closely spaced, calculate the magnetic field inside the coil, a distance r from the center.

5. Pie Shaped! (2 pts): A current path shaped as shown below produces a magnetic field at point P, the center of the arc. If the arc subtends an angle of 30 degrees and the total length of the wire in the "pie-shaped" part of the path is 1.2 m, what are the magnitude and direction of the frield produced at point P if the current is 3A? Ignore the contribution to the field due to the current in the small arcs near P.



6. Wire force (2 pts): Find the force between two parallel wires each carrying a steady current.

7. Introducing: The Vector Potential (4 pts): If $\vec{B}$ is uniform, show that

$$\vec{A} = -\frac{1}{2}(\vec{r} \times \vec{B})$$

works. That is check

$$\vec{\nabla} \cdot \vec{A} = 0 \quad \& \quad \vec{\nabla} \times \vec{A} = \vec{B}$$

Is this a unique result or are there other functions with the same divergence and curl?

11.) A Steady Current (4 pts): Please do Problem 5.14 in Text Book

12.) More (2 pts): Please do Problem 5.9 in Text Book

13.) More (2 pts): Please do Problem 5.38 in Text Book

14.) More – Just Being Evil at this point (2 pts): Please do Problem 5.52 in Text Book