**Problem 1** (15 pts)
An interstellar dust grain, roughly spherical with a radius of $3 \times 10^{-7}$ m, has acquired a negative charge such that its potential is $-0.15$ V. The mass of this grain is $10^{-16}$ kg. Suppose it is moving freely with speed $v \ll c$, in a plane perpendicular to the interstellar magnetic field $3 \times 10^{-6}$ Gauss. How many years it take to complete a circular path?

**Problem 2** (13 pts)
According to observers in the frame F, the following events occurred in the $xy$ plane. A singly charged positive ion which had been moving with constant velocity $v = 0.6\, c$ in the positive $y$-direction passed through the origin at $t = 0$. At the same instant a similar ion which had been moving at the same speed, but in the negative $y$-direction, passed the point $(2, 0, 0)$ on the $x$ axis. The distances are in cm.
(i) What is the strength and direction of the electric field, at $t = 0$, at the point $(3, 0, 0)$?
(ii) What is the direction of the magnetic field in this point?
(iii) What is the strength of the magnetic field in this point?

**Problem 3** (10 pts)
Consider a perfectly conducting disk of radius $r_0$ in a constant magnetic field $B$ perpendicular to the plane of the disk. Sliding contacts are provided at the edge of the disk ($C_1$) and at its axle ($C_2$). This system is Faraday’s “homopolar generator”. When turned at constant angular velocity, it provides a large direct current with no ripple. A torque is produced by a mass $M$ hung on a long string wrapped around the perimeter of the disk.
(i) Explain how and why a current flows.
(ii) Give a quantitative expression for the current as a function of angular velocity.
(iii) (*Extra 5 points*) Given a long enough string, this system will reach a constant angular velocity $\omega_f$. Find this $\omega_f$ and the associated current.