UNIVERSITY OF LEIPZIG
INSTITUTE FOR THEORETICAL PHYSICS
Department: Theory of Elementary Particles

TP2 2015

Lecturer: PD Dr. A. Schiller

List of problems 11

(31. and 32. required, use 33. to collect an additional point)

31. A circular wire of radius R carries a current I. A sphere of radius a ($a \ll R$) made of paramagnetic material with permeability μ is placed with its center at the center of the circuit.
Determine the magnetic dipole moment of the sphere resulting from the magnetic field of the current $\mathbf{B}_0$ (assumed to be uniform at the scale of the small sphere).
Determine the force per unit area $\mathbf{f}$ on the sphere using the effective surface current density $\boldsymbol{\lambda}_e$ due to the magnetization of the sphere ($\mathbf{f} = \boldsymbol{\lambda}_e \times \mathbf{B}_0$).

    Hint: Since $a \ll R$, think of the sphere as being in a uniform magnetic field $\mathbf{B}_0$ and make use of the magnetic scalar potential to determine the magnetic induction inside the sphere.

32. A circular wire loop of radius R is rotating uniformly with angular velocity ω about a diameter PQ. At its center, and lying along this diameter, is a small magnet of total magnetic moment $\mathbf{m}$.
What is the induced electromotive force (emf) between the point P (or Q) and a point on the loop mid-way between P and Q?

33. Consider a square loop of wire, of side length l, lying in the x, y-plane at $z = 0$ [corners $(0, 0, 0)$, $(l, 0, 0)$, $(0, l, 0)$, $(l, l, 0)$].
Suppose a particle of charge q is moving with a constant velocity v, where $v \ll c$, in the x, z-plane at a constant distance z_0 from the x, y-plane. (Assume the particle is moving in the positive x direction with $y = 0$.)
At $t = 0$ the particle cross the z-axis. Thus, at time t the position of q is $(vt, 0, z_0)$.
Give the induced electromotive force (emf) in the loop as a function of time.
Hint: To get the magnetic field at an observation point (x, y, z), use the Biot and Savart law with the current $\mathbf{I} = q\mathbf{v} = qv\,\mathbf{e}_x$. Thus, the time dependence in the magnetic field is a result of the changing distance between the moving charge and the observation point.