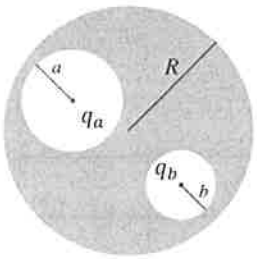
Electrodynamics I exam **March 3, 2020**

Please note the following:

- Write your name or student number on every paper that you hand in, including your one-page hand-written sheet.
- Explain (shortly) you reasoning in words also for the problems that involve calculations!

Answer either problem 1 *or* problem 2!

1. (a) Describe shortly the static fields **E**, **P**, **D**, **B**, **M** and **H**. (What are their underlying laws? How can the fields be measured? What causes the fields? What kind of constitutive relations relate the fields?) [*4 p*]
   (b) Describe how the magnetic force breaks the basic laws of Newtonian mechanics. [*2 p*]
2. Two spherical cavities (radii a and b) are hollowed out from the interior of a neutral conducting sphere of radius R (see figure below). At the center of each cavity a point charge is placed.
   (a) Find the surface charges σ_a, σ_b and σ_R [*1 p*]
   (b) What is the field outside the conductor? [*1 p*]
   (c) What is the field within each cavity? [*1 p*]
   (d) What is the force on q_a and q_b? [*1 p*]
   (e) Which of these answers would change if a third charge q_c were brought near the conductor? [*2 p*]



Answer either problem 3 *or* problem 4!

3. A spherical conductor (radius a) carries a charge Q. It is surrounded by linear dielectric material of susceptibility χ_e out to radius b. Find the energy of this configuration. [*6 p*]
4. Consider a system consisting of two coils with a current I_1 flowing through coil 1 and current I_2 flowing through coil 2. Starting from the expression

$$U = \frac{1}{2}\int \mathbf{J}\cdot\mathbf{A}\,dV$$

   determine the energy in the system in terms of current and inductance. [*6 p*]

5. A current I flows down a long straight wire of radius a. The wire is made of linear material with magnetic susceptibility χ_m, and the current is distributed uniformly.

   (a) What is the magnetic field a distance s from the axis? [*2 p*]

   (b) Find all the magnetization currents. [*2 p*]

   (c) What is the *net* magnetization current flowing down the wire? [*2 p*]

6. A parallel-plate capacitor consists of two parallel circular plates (capacitance C), between which there is an imperfect insulating matter (dielectric with permittivity ϵ, conductivity σ). Let the capacitor be charged to a potential difference $\Delta\varphi$ after which it is isolated. Determine:

   (a) the charge of the capacitor as a function of time. [*2 p*]

   (b) the displacement current in the dielectric. [*2 p*]

   (c) the magnetic field in the dielectric. [*2 p*]

7. A rectangular loop of conducting wire is placed entirely in a uniform magnetic field so that the plane of the loop is perpendicular to the field (the magnetic field is pointing out of the paper, see the figure below). A movable conducting crossbar connecting the two longer sides of the loop is made to move with a constant velocity v. Determine the currents in the system when the crossbar is at $x = l$. Both the wire and the crossbar have a resistance per unit length r. You do not need to take into account the inductance. [*6 p*]