E&M
UNIVERSITY OF TWENTE.

E&M Test 1
March 14th 2022

Boller, Offerhaus, Dhallé

201300164 & 201300183
Fields and electromagnetism

Instructions

You have **2 hours** to complete the test. Clearly indicate your name and student number on every sheet that you hand in.

You may use a hand-written formula sheet containing maximum 10 equations. <u>This sheet must be handed in together with your answers</u>.

Before answering the questions, read all of them and start with the one you find easiest.

The amount of points to be obtained with each question is indicated next to the question number.

Problem 1 (20pts/100)

A straight wire with a homogenous positive charge distribution is suspended at a fixed distance above a flat thick neutral *metal* plate. A cross-sectional view, in a plane perpendicular to the wire, is depicted in figure 1 below.

Copy the image and draw the field-lines for the electric field in this cross-section. Make sure to pay attention to the direction of the lines and their density. Make sure that you include field lines in all areas (above the wire, in-between the wire and the plate and below the plate.

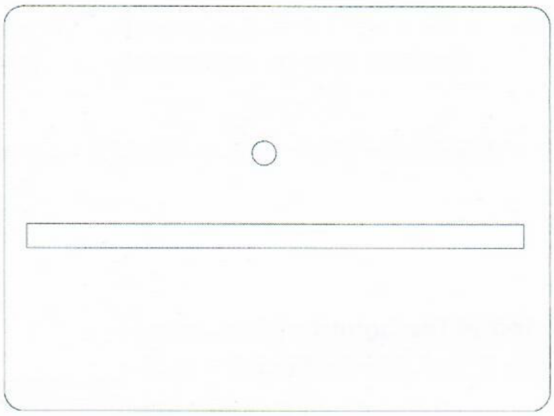

Figure 1 Cross-section of positively charged wire above neutral thick metal plate

Problem 2 (20pts/100)

Calculate the electric field at the center of a *partial* spherical shell that carries a uniform surface charge density $+\sigma$ and extends from $\theta = 3/4\pi$ to π (with θ the usual polar angle in spherical coordinates).

Problem 3 (20pts/100)

Below you find 8 statements. For each of them, indicate whether the statement is 'true' **(T)** or 'not true' **(NT)**. Also include a brief argument why you agree or not (**minimum** 1 & **maximum** 5 lines per statement). Read the statements carefully, each word may be important!

3.a. In electrostatics, any closed path-integral of the electric field equals zero.

3.b. In a region of space where there is no charge present, the electric field strength must be constant.

3.c. The sum of all charges within a given closed surface is exactly zero. Therefore, the flux of the electric field through any part of this surface must be zero.

3.d. Far away from an electrical dipole, the electric field strength on its axis decreases as 1/r3 (with r the distance to the dipole).

3.e. If A and B are two points that lie close toghether, but *not* on the same equipotential surface, the electric field strength in A and B must be different.

3.f. Two metal disk-shaped plates of radius R are placed parallel to each other, at a distance $d << R$ apart. One plate caries a surface charge density $+\sigma$, the other $-\sigma$. The attraction force between these disks is proportional to $1/d$.

3.g. The space in-between the disks of question 3.f is now filled with water (while keeping $\pm\sigma$ and d constant), which has a relative permittivity $\varepsilon_r = 80$. Due to the water, the force between the disks increases with a factor 80.

3.h. The charge distribution on a conducting sphere is always spherically symmetric, irrespective of the sphere's surroundings.

Problem 4 (25pts/100)

Consider a dielectric sphere of radius R with relative permittivity ε_r and a frozen-in volumetric free charge distribution $\rho(r) = \frac{Q}{2\pi R^2}\frac{1}{r}$

4.a Work out a vector expression for the electric field **E** as a function of *r*, the distance to the center of the sphere. Make sure to express the field both in- and outside the sphere. Create a graph of the magnitude of **E** as a function of *r*.

4.b Work out the electric potential V_0 at the origin as function of the parameters Q and R (assuming $V(r)$ to be zero at $r = \infty$).

Problem 5 (15pt/100)

Electric field lines are refracted at the boundary between dielectrics. Referring to figure 2, an electric field **E** hits a dielectric plate of thickness d and permittivity ε under an angle θ_1 (measured with respect to the normal direction to the plate). After transition through the plate, the point of exit is shifted over a distance a along the plate with respect to the point of entry.

Calculate this distance a (as a function of the parameters ε, d and θ_1) for the case that there is no free charge present in the problem.

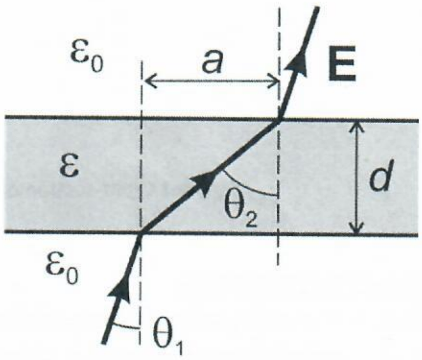

Figure 2: Refraction of an **E**-field by a dielectric plate (problem 5).