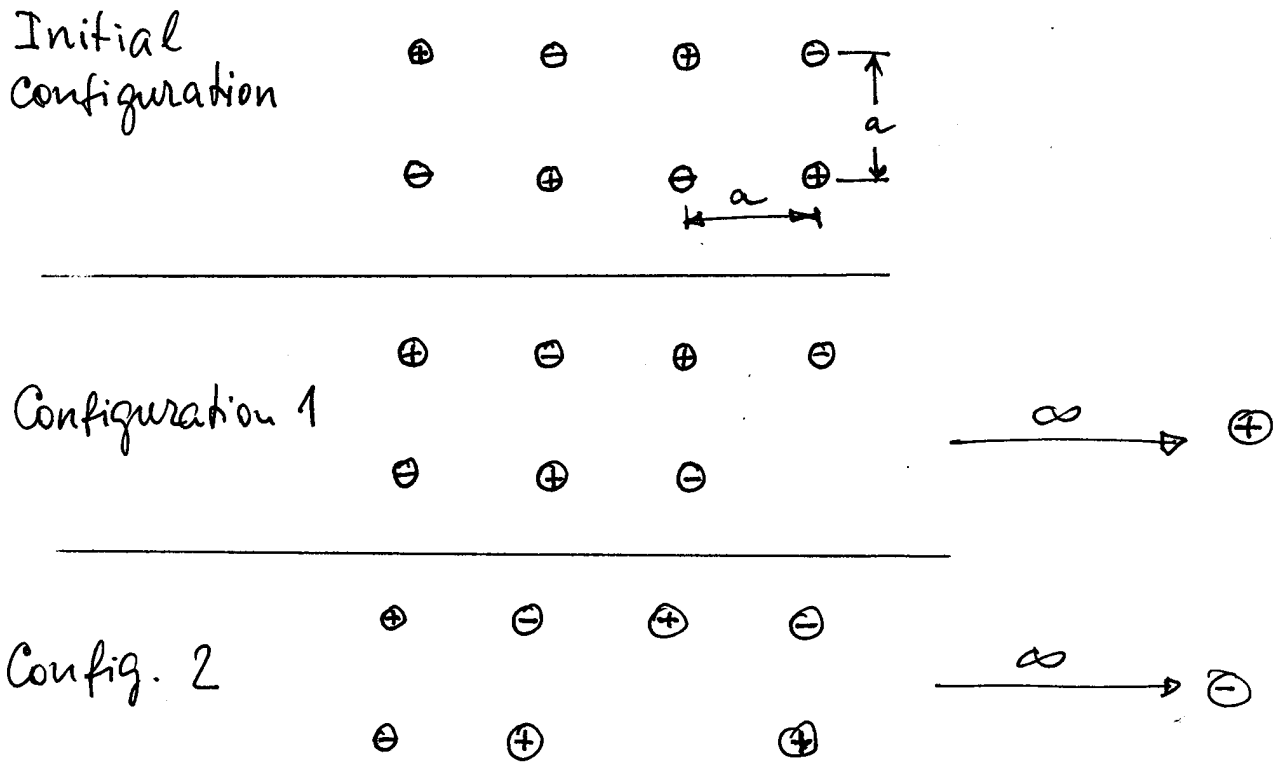
MIDTERM EXAM (total 100 points)

Electromagnetics (PHYS-4211)

1) (25 points) The cluster of point charges ( $+q$ and $-q$ ) is initially arranged in a pattern shown on the figure. Then one of the charges is removed from the cluster in two possible ways: configurations 1 and 2.

- What will be the electrostatic energy gain (or loss) associated with the transition between the initial and each of the final configurations?
- Explain observed difference in the magnitude of the electrostatic energy gain (or loss) for configuration 1 and 2.

*Note*: Express the result for energy in units of $q^2/(4\pi\epsilon_0 a)$



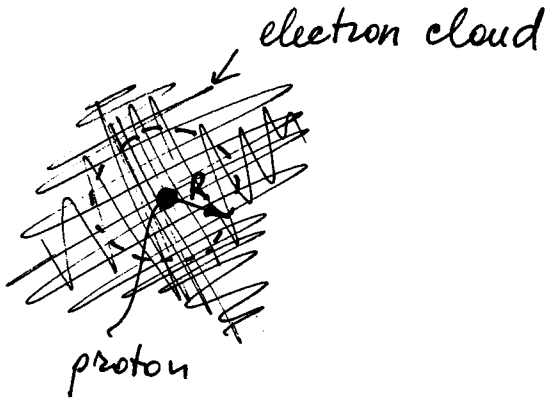
2) (25 points) The hydrogen atom consists of a proton with the charge $+q_e$ surrounded by an electron cloud with the density $\rho(\vec{r})$ centred at the proton with the radial distribution

$$\rho_e(r)=\frac{-q_e}{\pi a^3}e^{-2r/a} \quad ,$$

where $a$ is the Bohr radius.

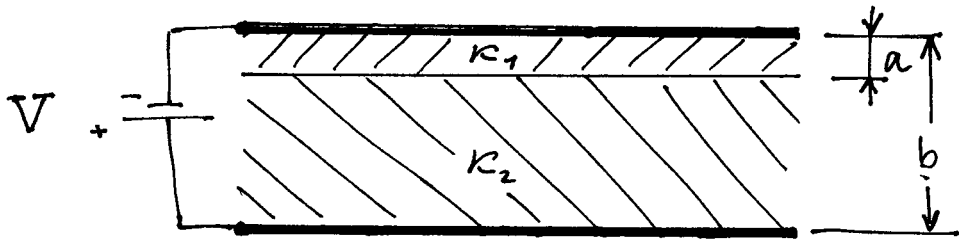
- Find direction and magnitude of the electric field at the distance $R$ from the proton.

*Note*: $R$ can be comparable to the Bohr radius.



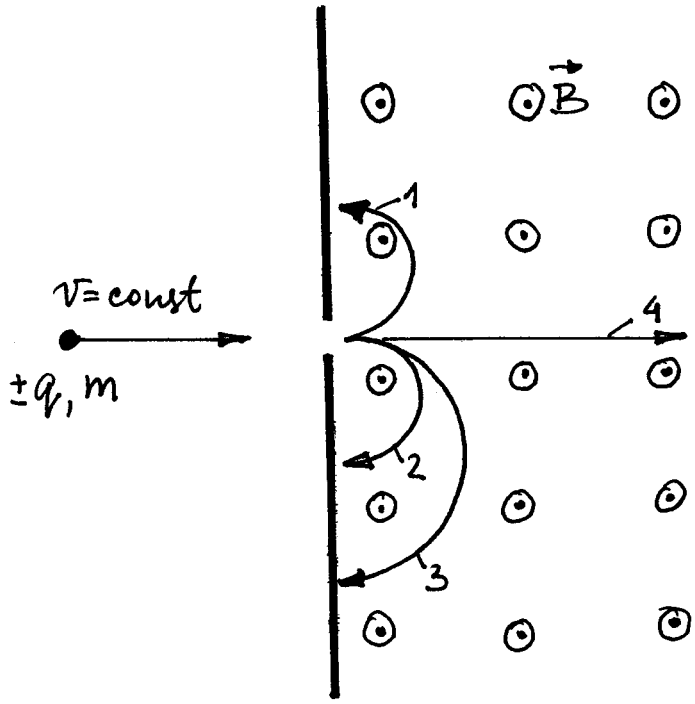

3) (20 points) Two dielectric layers with different dielectric constants ( $\kappa_1<\kappa_2$ ) are sandwiched between metal plates with the constant potential difference $V$ , which is maintained by a battery.

- Find a magnitude of the electric field $E_1$ and $E_2$ in both layers.
- How does $E_2$ change (increase or decrease) with decreasing of the 1st layer thickness $a$ ?
- Which value does $E_2$ approach, as $a\to 0$ ?



4) (15 points) Charged particles, which move with the constant velocity, enter the uniform magnetic field and form four possible trajectories shown on the figure.

- Based on the trajectories, conclude on the sign of the particle charge as well as on their relative mass. Justify your arguments.




5) (15 points) The chart below presents various magnetic effects, their relative strength, materials in which the particular effect is most pronounced as well as description of the corresponding physical mechanisms.

- Connect relevant pieces together from left to the right. Justify the material selection.

| | | | |
|---|---|---|---|
| Very strong | Paramagnetism | Fe | Induced change of the orbital magnetic moment |
| weak | Ferromagnetism | $H_2$ | Spin alignment due to external magn. field |
| very weak | Diamagnetism | $O_2$ | Spin - Spin exchange interaction |