Short Problem 1: (10 points)

A charge $+q$ is brought to the position as shown in the figure. The xy plane is a grounded conductor.

(a) Find the electric potential in the space above the xy plane;
(b) Find the force on the charge $+q$;
(c) Find the surface-charge density induced on the plane;
(d) Find the work needed to remove the charge $+q$ to infinity.
Short Problem 2:  (10 points)

The rim of a wheel of radius b is charged with a linear charge density \( \lambda \). The wheel is suspended horizontally and is free to rotate. The spokes are made of some non-conducting material. In the central region out to a radius \( a < b \) is a uniform magnetic field \( B \) pointing up: see Figure. Explain qualitatively what happens to the wheel when somebody turns the B-field off, and compute the resulting angular momentum given to the wheel.
Long Problem 1:

The electric potential of a given setup is written as

\[ V(r) = Ae^{-\lambda r/r} \]

where \( A \) and \( \lambda \) are constants.

a) Find the Electric Field \((E(r))\) for this setup.

b) Find the total charge \((Q)\) corresponding to this potential.

c) Calculate the force a doubly charged ion \((Z^{++})\) would experience in this potential.
**Long Problem 2: (20 points)**

A closed loop is made of a U-shaped metal wire of negligible resistance and a movable metal crossbar of resistance $R$. The crossbar has mass $m$ and length $L$. It is initially located a distance $h_0$ from the other end of the loop. The loop is placed vertically in a uniform horizontal magnetic field of magnitude $B_0$ in the direction shown in the figure. The crossbar is released from rest and slides with negligible friction down the U-shaped wire without losing electrical contact. Express all algebraic answers to the questions below in terms of $B_0$, $L$, $m$, $h_0$, $R$, and fundamental constants, as appropriate.

![Diagram of the crossbar and loop](image)

**a)** Determine the magnitude of the magnetic flux through the loop when the crossbar is in the position shown.

**b)** On the figure below, indicate the direction of the current in the crossbar as it falls.

Justify your answer.

**c)** Calculate the magnitude of the current in the crossbar and express it as a function of the crossbar’s speed $u$ when it falls.

**d)** Derive, but do NOT solve, the differential equation that could be used to determine the speed $u$ of the crossbar as a function of time $t$.

**e)** Determine the terminal speed $u_T$ of the crossbar.