CRT - old TV sets

A key part of a television set used to be an electron gun. Electrons emitted with small velocity from a hot tungsten filament are accelerated through a potential difference of about 100 Volts before they are steered to the screen. The electron gun you will design will consist of the hot filament and two identical annuli, one charged negatively and one positively. The annuli are spaced a distance $d$ apart. Assume for simplicity that the surface charge density $\sigma$ on the annuli are uniform. (This would not be the case for conducting annuli held at fixed voltages but is a reasonable first approximation.)

![Diagram showing electron gun and annuli]

**a)** Determine the potential created by one ring of charge $dQ$ with radius $r$ at a point on the axis of the ring at a distance $x$ from the center of the ring.

**b)** Similar to homework 1, integrate the voltages from the infinitesimal rings of charge to determine the voltage $V(x)$ due to one annulus with inner radius $a$ and outer radius $R$. Determine $V(0)$ and show that $V(x) \to 0$ as $x \to \infty$.

**c)** Show by differentiating $V(x)$ with respect to $x$ that this voltage gives the electric field determined in homework 1.

**d)** Now design an electron gun by placing a negatively charged annulus at $x=0$ and a positively charged one at $x=d$. Determine the voltage difference between the point $x=0$ and $x=\infty$.

**e)** Assume the following geometry: $R=10a$ and $d=5a$. Plot the electric field and voltage in dimensionless form as a function of $x/a$. Show that an electron released from rest very close to, but just outside, the hole in the negative plate will accelerate through the hole, pass through the region between the plates and will continue on to $x=\infty$.

**f)** Determine the charge density $\sigma$ necessary so the voltage at $x=0$ is -100 Volts. Use specific values $a=1$ mm, $d=5$ mm, $R=10$ mm. Determine the velocity of the electron at $x=d$ and the final velocity of the electron for the case where the initial velocity is zero.