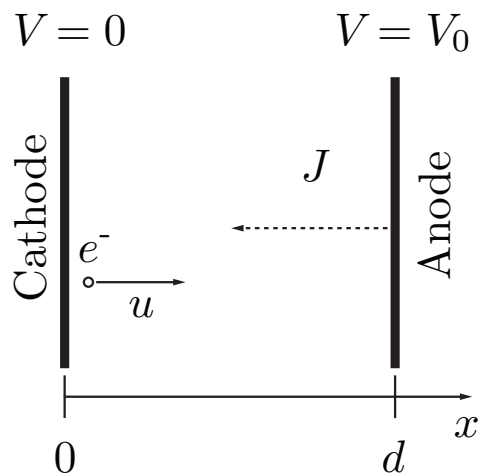


## Section B. Electricity and Magnetism

### 1. Space charge

Consider two parallel plates of infinite extent separated by distance  $d$ . A constant potential difference  $V_0 > 0$  is maintained between the cathode and the anode. Electrons are released from the cathode at zero potential with negligible velocity and are accelerated to the anode by the electric field. The region between the plates is a vacuum except for the electrons that are emitted into it. This leads to a finite space charge density,  $\rho(x)$ , where  $x$  is the distance away from the cathode (see picture). Under steady state conditions,  $\rho(x)$  is independent of time, and the continuity equation implies that the current density  $J = \rho u$  is independent of  $x$ , where  $u(x)$  is the velocity of the electrons.



- Use Poisson's equation and conservation of energy to find the potential  $V(x)$  as a function of  $x$ .
- Find an explicit expression for the current density  $J$  in terms of  $V_0$ .