4-3)

Review some relationships:

$$C_{PPC} = \frac{\kappa\varepsilon_o A}{L} \qquad R = \frac{\rho L}{A} \qquad V = I\,R \qquad V = \frac{Q}{C}$$

Here, I've used L to represent the plate separation to avoid confusion later in the solution.

So then,

$$I = \frac{V}{R} = \frac{Q/C}{\left(\frac{\rho L}{A}\right)} = \frac{Q/\left(\frac{\kappa\varepsilon_o A}{L}\right)}{\left(\frac{\rho L}{A}\right)} = \frac{QLA}{\kappa\varepsilon_o \rho LA} = \boxed{\frac{Q}{\kappa\rho\varepsilon_o}} \quad .$$

Now, the current is the rate at which the charge on the capacitor <u>decreases</u>, so

$$I = -\frac{dQ}{dt} = \frac{Q}{\kappa\rho\varepsilon_o} \quad .$$

Re-arrange to get

$$\frac{dQ}{Q} = -\frac{dt}{\kappa\rho\varepsilon_o}$$

and integrate both sides from the initial condition Q_o at t = 0 to the some later condition Q at time t:

$$\int_{Q_o}^{Q} \frac{dQ}{Q} = -\int_0^t \frac{dt}{\kappa\rho\varepsilon_o}$$

$$\ln Q\Big|_{Q_o}^{Q} = \ln\left(\frac{Q}{Q_o}\right) = -\frac{t}{\kappa\rho\varepsilon_o} \quad .$$

Exponentiate:

$$\frac{Q}{Q_o} = e^{-\frac{t}{\kappa\rho\varepsilon_o}}$$

$$\boxed{Q = Q_o\, e^{-\frac{t}{\kappa\rho\varepsilon_o}}}$$