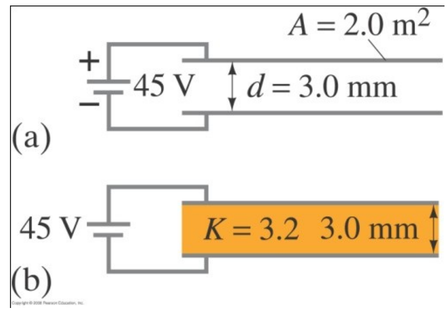
**95.** A parallel-plate capacitor with plate area $A = 2.0\ \text{m}^2$ and plate separation $d = 3.0\ \text{mm}$ is connected to a 45-V battery (Fig. 24–40a). (*a*) Determine the charge on the capacitor, the electric field, the capacitance, and the energy stored in the capacitor. (*b*) With the capacitor still connected to the battery, a slab of plastic with dielectric strength $K = 3.2$ is placed between the plates of the capacitor, so that the gap is completely filled with the dielectric. What are the new values of charge, electric field, capacitance, and the energy $U$ stored in the capacitor?




[Solution]

(*a*) Use Eq. 24-2 to calculate the capacitance.

$$C_0 = \frac{\varepsilon_0 A}{d} = \frac{\left(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2\right)\left(2.0\ \text{m}^2\right)}{\left(3.0\times10^{-3}\ \text{m}\right)} = \boxed{5.9\times10^{-9}\ \text{F}}$$

Use Eq. 24-1 to calculate the charge.

$$Q_0 = C_0 V_0 = \left(5.9\times10^{-9}\ \text{F}\right)\left(45\ \text{V}\right) = 2.655\times10^{-7}\ \text{C} \approx \boxed{2.7\times10^{-7}\ \text{C}}$$

The electric field is the potential difference divided by the plate separation.

$$E_0 = \frac{V_0}{d} = \frac{45\ \text{V}}{3.0\times10^{-3}\ \text{m}} = \boxed{15000\ \text{V/m}}$$

Use Eq. 24-5 to calculate the energy stored.

$$U_0 = \tfrac{1}{2} C_0 V_0^2 = \tfrac{1}{2}\left(5.9\times10^{-9}\ \text{F}\right)\left(45\ \text{V}\right)^2 = \boxed{6.0\times10^{-6}\ \text{J}}$$

(*b*) Now include the dielectric. The capacitance is multiplied by the dielectric constant.

$$C = KC_0 = 3.2\left(5.9\times10^{-9}\ \text{F}\right) = 1.888\times10^{-8}\ \text{F} \approx \boxed{1.9\times10^{-8}\ \text{F}}$$

The voltage doesn't change (it's maintained by the battery). Use Eq. 24-1 to calculate the charge.

$$Q = CV = KC_0V = 3.2\left(5.9\times10^{-9}\ \text{F}\right)\left(45\ \text{V}\right) = 8.496\times10^{-7}\ \text{C} \approx \boxed{8.5\times10^{-7}\ \text{C}}$$

Since the battery is still connected, the voltage is the same as before, and so the electric field doesn't change.

$$E = E_0 = \boxed{15000\ \text{V/m}}$$

Use Eq. 24-5 to calculate the energy stored.

$$U = \tfrac{1}{2} CV^2 = \tfrac{1}{2} KC_0V^2 = \tfrac{1}{2}(3.2)\left(5.9\times10^{-9}\ \text{F}\right)\left(45\ \text{V}\right)^2 = \boxed{1.9\times10^{-5}\ \text{J}}$$