4. A parallel plate capacitor has electrical energy $2.4 \times 10^{-5}$ ergs when connected to a 3 V battery. It is now disconnected from the battery. A slab of dielectric constant $\kappa = 4$ and nearly the same thickness as the capacitor is slid into the capacitor.

a. (3 pts) What was the initial charge on the plates?

$$ U_i = \frac{1}{2} C (3V)^2 = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} Q (3V) \quad \Rightarrow Q = \frac{2U}{3V} = \frac{4.8 \times 10^{-2} J}{3V} = 1.6 \times 10^{-2} C. $$

b. (3 pts) What is the final charge on the plates?

$$ Q_{\text{final}} = Q_{\text{initial}} = 1.6 \times 10^{-2} C. $$

c. (3 pts) What is the final voltage difference?

$$ \Delta V_f = \frac{\Delta V_{\text{initial}}}{\kappa} = \frac{3V}{4} = 0.75 V. $$

d. (3 pts) What is the final electrical energy?

$$ U_f = \frac{1}{2} Q_f \cdot \Delta V_f = \frac{1}{2} \cdot 1.6 \times 10^{-2} C \cdot 0.75 V = 0.6 \times 10^{-2} C. $$

e. (3 pts) Was the dielectric attracted, repelled, or did it feel no force when it was part way in the capacitor? No reason, no credit.

5. A voltaic cell has internal resistance $r = 0.3 \Omega$ and open circuit voltages across the left and right electrodes of 0.3 V and 1.5 V, for a net emf of $E = 1.8$ V. It is in series with a resistor $R = 0.6 \Omega$. Let $V_a = 0.4$ V. The connecting wires have zero resistance.

a. (10 pts) Find the current, the voltage drops across the resistances, and sketch the voltage around the circuit.

$$ I = \frac{E}{R + r} = \frac{1.8 V}{0.6 \Omega + 0.3 \Omega} = 2 A $$

$$ I_R = 0.6 V, \quad I_C = 1.2 V. $$

b. (5 pts) If the voltaic cell discharges in 40 minutes, find its initial "charge" and its initial energy.

$$ Q = I t = 2 A \cdot (40 \times 60 s) = 4800 C. $$

$$ U_0 = E Q_0 = (1.8 V) (4800 C) = 8640 J. $$