19.P.66 Insert plastic into a capacitor

(a) In the final state of static equilibrium there is no E inside the resistor and wires, so the round-trip potential difference is $(+\text{emf}) + (-\Delta V_{\text{cap}}) = 0$. Therefore $Q = C\Delta V_{\text{cap}} = C \cdot \text{emf}$.

(b) Field argument: Polarized molecules in plastic contribute a field just outside the capacitor that is in the opposite direction to the fringe field of the plates, so field due to capacitor(plates and plastic) is reduced. The net field had been zero and is now nonzero due to the reduction in the field contributed by the capacitor, so current runs. The current will run until the fringe field of the capacitor again is large enough to cancel the field of all other charges.

Potential argument: E inside gap is reduced by a factor of $1/K$, so $\Delta V_{\text{cap}} = Es$ is reduced to $\Delta V_{\text{cap}} = \text{emf}/K$. That means that the loop rule requires a potential difference across the resistor, and hence current will run until the potential difference across the capacitor is again equal to emf.

(c) E inside gap is reduced by a factor of $1/K$, so $\Delta V_{\text{cap}} = Es$ is reduced to $\Delta V_{\text{cap}} = \text{emf}/K$. The loop rule becomes $(+\text{emf}) + (-\text{emf}/K) + (-RI) = 0$, and the initial current is

$$I = \frac{\text{emf}}{R}\left(1 - \frac{1}{K}\right)$$

(d) The effective capacitance has changed: $C_{\text{new}} = \dfrac{Q}{\Delta V} = \dfrac{Q}{Es} = \dfrac{Q}{\left(\dfrac{(Q/A)}{K\varepsilon_0}\right)} = K\left(\dfrac{\varepsilon_0 A}{s}\right) = KC$

$$Q_{\text{new}} = C_{\text{new}}(\text{emf}) = KC(\text{emf})$$

19.P.67 A battery with internal resistance

a) Around the loop: $\Delta V_{\text{batt}} + \Delta V_{\text{wire}} = 0$, and if $\Delta V_{\text{wire}} \approx 0$, we have $\Delta V_{\text{batt}} = \text{emf} - r_{\text{int}} I \approx 0$, so

$$r_{\text{int}} = \frac{\Delta V_{\text{batt}}}{I} = \frac{9\text{ V}}{18\text{ A}} = 0.5\ \Omega$$

b) Power $P = I\Delta V = (18\text{ A})(9\text{ V}) = 162$ watts generated by the battery.

c) Power $P = I\Delta V = I^2 R = (18\text{ A})^2\ (0.5\ \Omega) = 162$ watts dissipated in the internal resistance or 162 J every second.. This makes sense because in this circuit there are no other resistors, so all the power input by the battery must be dissipated in the internal resistance.

d) Around the loop: $\Delta V_{\text{batt}} + \Delta V_{\text{resistor}} = 0$, so we have $\text{emf} - r_{\text{int}} I - RI = 0$:

$$I = \frac{\text{emf}}{(R + r_{\text{internal}})} = \frac{9\text{ V}}{10.5\ \Omega} = 0.86\text{ A}$$

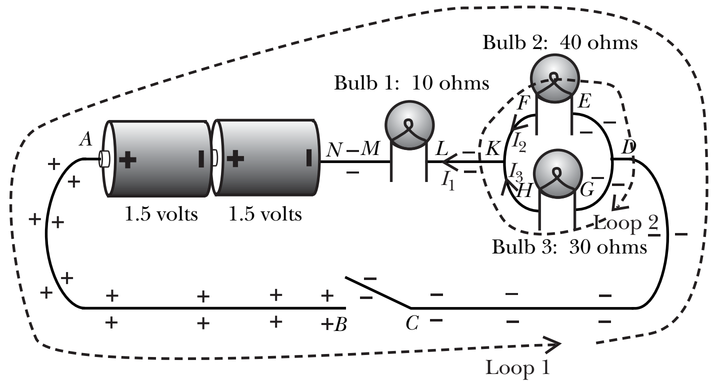
e) Power $P = I\Delta V = I^2 R = (0.86\text{ A})^2 (10\text{ W}) = 7.4$ W dissipated in the 10 Ω resistor.

f) $\Delta V = +\,\text{emf} - I\, r_{\text{int}} = +9\text{ V} - (0.86\text{ A})(0.5\text{ W}) = +8.6\text{ V}$

19.P.69 Three bulbs

(a) With switch open, no current; surface charge + on left branch, – on right branch. There is an electric field in the gap between the two parts of the switch.

The diagram shows the approximate charge distribution. It also defines loop and current directions we will use after closing the switch.



(b) Round trip starting at C, going clockwise:

$(V_B - V_C) + \Delta V_{\text{wire}} + \Delta V_{\text{batteries}} + \Delta V_{\text{wire}} = 0$

Static equilibrium, so $\Delta V_{\text{wire}} = 0$, since $E = 0$ in the wires.

$(V_B - V_C) + (-3 \text{ volts}) = 0$, so $(V_B - V_C) = +3$ volts

$V_D - V_K = 0$ since static equilibrium, and $E = 0$ in the wires.

(c) We need 3 equations since there are 3 unknown currents, shown on the diagram:

Loop 1: $(-R_2 I_2) + (-R_1 I_1) + (+3 \text{ volts}) = 0$ Loop 2: $(-R_3 I_3) + (+R_2 I_2) = 0$

Node K: $I_2 + I_3 = I_1$

(d) Starting at F and traveling to C: $V_F + R_2 I_2 + 0 = V_C$, so $V_C - V_F = R_2 I_2$

(e) Power output of batteries = $I_1 (\Delta V) = I_1 (3 \text{ V})$

(f) To solve the 3 simultaneous equations, if we eliminate I_1 we reduce the problem to 2 equations:

The loop equations can be written like this: $10(I_2 + I_3) + 40 I_2 = 3$ and $40 I_2 = 30 I_3$

Eliminate $I_3 = \frac{4}{3} I_2$: $10\left(I_2 + \frac{4}{3} I_2\right) + 40 I_2 = 3$, so $I_2 = \dfrac{3}{\left(10 \times \frac{7}{3}\right) + 40} = 0.0474$ A

$I_3 = \frac{4}{3} I_2 = 0.0632$ A, $I_1 = I_2 + I_3 = 0.047 + 0.063 = 0.1106$ A

(g) $i = \dfrac{0.110 \text{ C/s}}{1.6 \times 10^{-19} \text{ C/electron}} = 6.88 \times 10^{17}$ electrons/s

(h) $V_C - V_F = I_2 (40\ \Omega) = (0.047\text{A})(40\ \Omega) = 1.88$ V

(i) Power output of batteries = $I_1 (\Delta V) = (0.110 \text{ A})(3 \text{ V}) = 0.33$ watt

(j) $E = \dfrac{\Delta V_2}{L_2} = \dfrac{R_2 I_2}{L_2} = \dfrac{(0.047 \text{ A})(40\ \Omega)}{(8 \times 10^{-3} \text{ m})} = 235$ V/m ; the cross-sectional area is irrelevant.