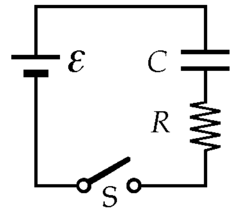
33. Consider a series RC circuit for which $R = 1.0\ \text{M}\Omega$, $C = 5.0\ \mu\text{F}$, and $\mathcal{E} = 30\ \text{V}$. The capacitor is initially uncharged when the switch is open. Find the charge on the capacitor 10 s after the switch is closed.



Solution If the switch S is closed at $t = 0$, the charge on the capacitor at any time later is

$$q = Q_{\max}\left(1 - e^{-t/\tau}\right)$$

Here, $\tau = RC$ is the time constant of the circuit. For the given circuit,

$$\tau = (1.0\ \text{M}\Omega)(5.0\ \mu\text{F}) = \left(1.0 \times 10^{6}\ \Omega\right)\left(5.0 \times 10^{-6}\ \text{F}\right) = 5.0\ \text{s}$$

The charge stored in the capacitor when it is fully charged (i.e., when current in the circuit has decreased to zero) is $Q_{\max}$. Note that if Kirchhoff's loop rule is applied to this circuit, with $I = 0$, the result is

$$+\mathcal{E} - \Delta V_c - R(0) = 0$$

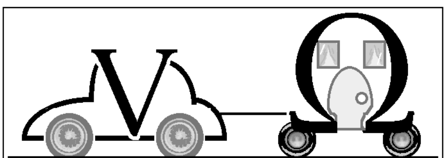
or when the capacitor is fully charged, the voltage across the capacitor is

$$\Delta V_c = Q_{\max}/C = \mathcal{E}$$

Thus, $$Q_{\max} = C\mathcal{E} = (5.0\ \mu\text{F})(30\ \text{V}) = 1.5 \times 10^{-4}\ \text{C} = 150\ \mu\text{C}$$

At $t = 10\ \text{s}$ after the switch is closed, the charge on the capacitor is:

$$q = (150\ \mu\text{C})\left[1 - e^{-(10\ \text{s})/(5.0\ \text{s})}\right] = (150\ \mu\text{C})\left[1 - e^{-2}\right] = 130\ \mu\text{C}$$ ◊



A **Volts**wagon towing a mobile **Ohm.**