# PHYS 2020: Homework 8 (due Wednesday Nov. 25)

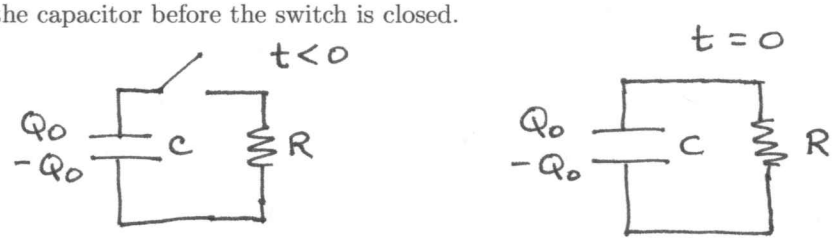
**Reading:** Purcell & Morin, Chapters 4.1–4.3, 4.7–4.11.

**Problem 1 (10 points):** The Large Hadron Collider consists of two beams of protons circulating in opposite directions around a ring 27 km in circumference. Suppose each beam consists of around $3 \times 10^{14}$ protons moving at $0.99999999c$, where $c$ is the speed of light. What is the current (in amperes) for each beam?

**Problem 2 (10 points):** Suppose that the solar wind consists mainly of protons being emitted from the Sun, such that $10^{36}$ protons are emitted per second with velocity 500 km/s. What would be the current density $J$ (in units $\mathrm{A/m^2}$) from the solar wind measured near the Earth? *Hint:* the Earth-Sun radius is around $1.5 \times 10^8$ km.

(Note: In reality, the solar wind also includes electrons so that it is approximately neutral. Otherwise the sun would acquire a net electric charge.)

**Problem 3 (10 points):** Consider an RC circuit consisting of a resistor (resistance $R$), a parallel plate capacitor (capacitance $C$), and a switch that allows current to flow. Initially, before the switch is closed, the capacitor carries charges $Q_0$ and $-Q_0$ on its plates. Suppose that the switch is closed at time $t = 0$ and current can flow. Show that the energy dissipated by the resistor is equal to the potential energy initially contained in the capacitor before the switch is closed.




**Problem 4 (25 points):** Consider the circuit shown below. For $t < 0$, the switch is open and the capacitors are uncharged. Suppose the switch is closed at $t = 0$ and current can flow.

(a) After the switch has been thrown at $t = 0$, what are the charges on the two capacitors as a function of time $t$? *Hint:* By symmetry, you may assume that the charges on the capacitors are identical. You may find help by looking at P&M, exercise 4.18. **(10 points)**

(b) Determine the energy dissipated by each individual resistor between $t = 0$ and $t = \infty$. **(5 points)**

(c) What is the potential energy stored in each capacitor for $t = \infty$? **(5 points)**

(d) What is the total work done by the battery between $t = 0$ and $t = \infty$? **(5 points)**

Your result for parts (b) and (c) should sum to give (d).