Problem 1 (15 points)

The switch in the circuit below has been open for a long, long time.

\[ I_2 \quad I_3 \]
\[ \quad R_2 \quad I_1 \quad R_1 \]
\[ V \]

Determine the currents $I_1, I_2, I_3$ in the resistors and in the self-inductor at the moment

a. the switch is closed,

b. a long time after the switch is closed.

The internal resistance of the battery is negligibly small. Express your answers ONLY in terms of $V, R_1, R_2$ and $L$. 
Problem 2 (12 points)

A current $I$ goes through a rectangular wire in the direction shown with arrows in the figure. The dimensions of the rectangle are $a$ and $b$ as shown. A uniform magnetic field of strength $B$ is in a direction perpendicular to the paper (it’s coming towards you), as shown. What is the torque on the rectangular loop?
Problem 3 (15 points)

A mass spectrometer accelerates doubly ionized atoms of charge $2e$ over a potential difference $V$ before they enter a uniform magnetic field $B$ which is perpendicular to the direction of motion of the ions. If $d$ is the radius of the ions’ path in the magnetic field, what is the mass $M$ of one ion? Express your answer ONLY in terms of $V$, $B$, $e$ and $d$. The potential $V$ is low enough that no relativistic corrections are needed.
Problem 4 (12 points)

Apply Faraday's law to show that a static electric field between the plates of a parallel-plate capacitor cannot drop abruptly to zero at the edges of the capacitor.
Problem 5 (15 points)

A current of $I$ Amperes runs through a very, very long wire of which a portion ($ACD$) is shown below. The direction of the current is indicated. The angle at $C$ is $90^\circ$. CA is straight, and it continues beyond A to the far left. CD is also straight and continues far beyond D. P is a distance $d$ meters from C; ACP is a straight line. What is the magnetic field in Tesla at P (magnitude and direction)? **Hint:** This problem can be done quickly without complicated math.
Problem 6 (15 points)

Two voltmeters, $V_{\text{right}}$ and $V_{\text{left}}$, each with an internal resistance of $10^6 \, \Omega$ are connected through wires of negligible resistance (see the circuit below). The “+” side of both voltmeters is up as shown. A changing magnetic field is present in the shaded area. At a particular moment in time $V_{\text{right}}$ reads $-0.1$ Volt (notice the $-$ sign).

a. What, at that moment, is the induced EMF (in Volts) in the circuit?

b. At that moment in time, what is the reading of $V_{\text{left}}$?
Problem 7 (16 points)

A conducting bar of length $D$ rotates with angular frequency $\omega$ about a pivot $P$ at one end of the bar (see the figure). The other end of the bar is in slipping contact with a stationary conducting wire in the shape of a circle (we only show a small part of that circle to keep the drawing simple). Between point $P$ and the circular wire there is a resistor $R$ as shown. Thus the bar, the resistor and the arc form a closed conducting loop. The resistance of the bar and the circular wire are negligibly small. There is a uniform magnetic field $B$ everywhere, it is perpendicular to the plane of the paper as indicated.

What is the induced current in the loop? Express your answer in terms of $D, \omega, R,$ and $B$. 