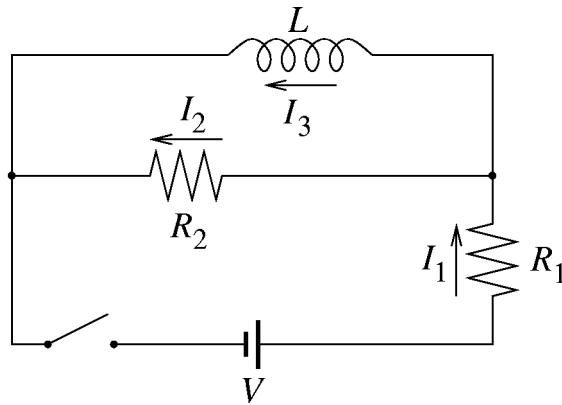


### Problem 1 (15 points)

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



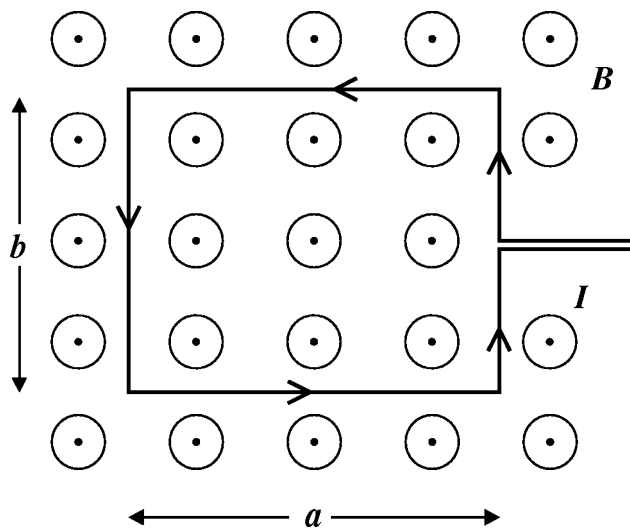
Determine the currents  $I_1, I_2, I_3$  in the resistors and in the self-inductor at the moment

- the switch is closed,
- 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)

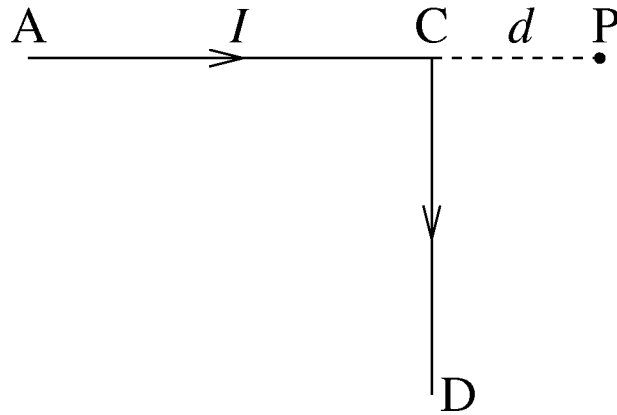
A mass spectrometer accelerates doubly ionized atoms of charge  $2e$  over a potential difference  $V$  before they enter a uniform magnetic field  $B$  which is perpendicular to the direction of motion of the ions. If  $d$  is the radius of the ions' path in the magnetic field, what is the mass  $M$  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)

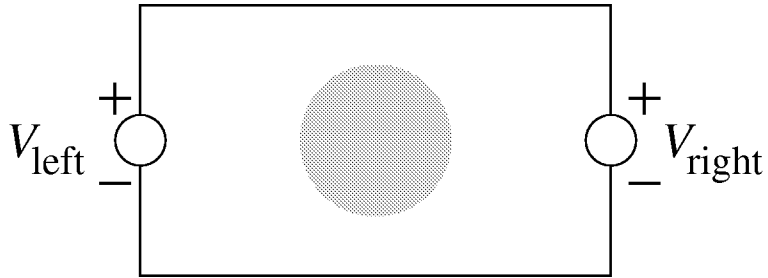
A current of  $I$  Amperes runs through a very, very long wire of which a portion ( $ACD$ ) is shown below. The direction of the current is indicated. The angle at  $C$  is  $90^\circ$ .  $CA$  is straight, and it continues beyond  $A$  to the far left.  $CD$  is also straight and continues far beyond  $D$ .  $P$  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).

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

