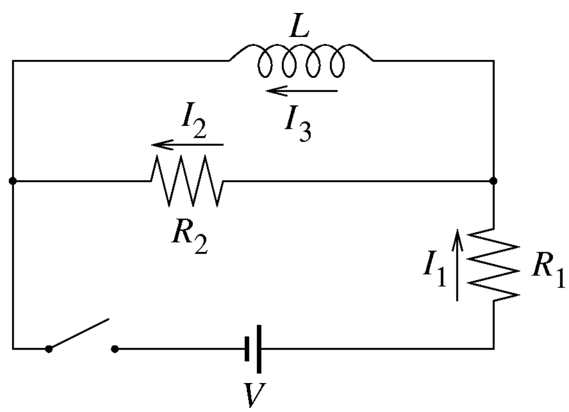
Problem 1 (15 points)

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

a. the switch is closed, $I_1 = I_2 = \frac{V}{R_1+R_2}$ $I_3 = 0$

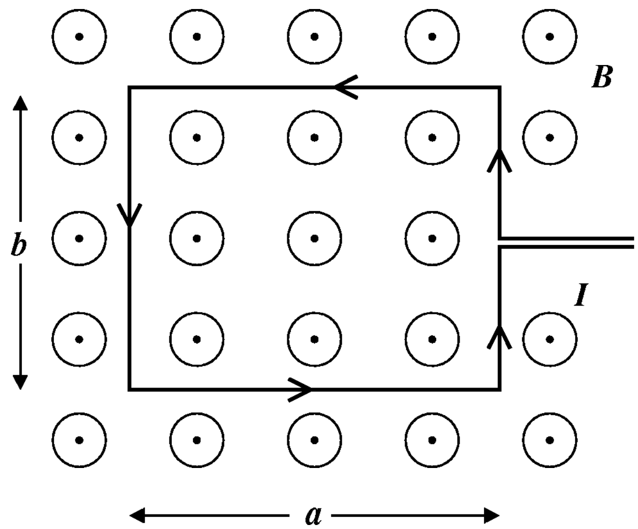
b. a long time after the switch is closed. $I_1 = I_3 = \frac{V}{R_1}$ $I_2 = 0$

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?

0 .



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**.

$$V \cdot 2e = \frac{1}{2} M v^2$$

$$v = 2\sqrt{\frac{Ve}{M}}$$

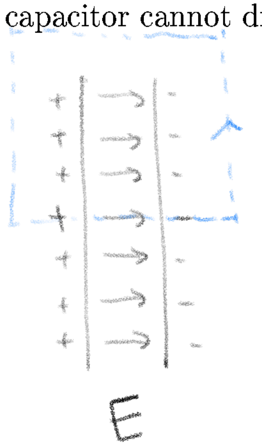
$$F = q(\vec{v} \times \vec{B}) = 2evB = 4eB\sqrt{\frac{Ve}{M}}$$

$$= Ma = M\frac{v^2}{d} = \frac{4V\cancel{e}}{d}$$

$$M = \frac{B^2 d^2 e}{V}$$

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.

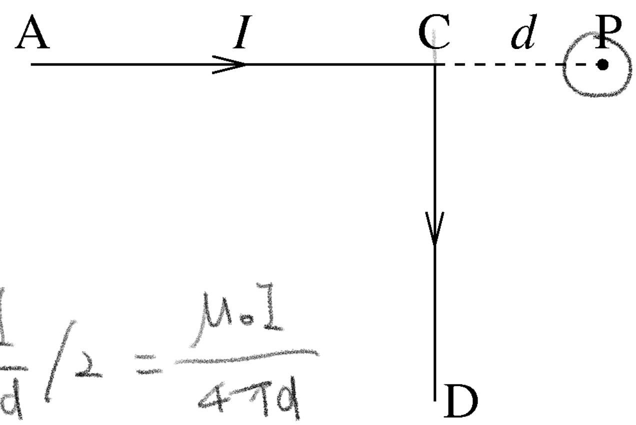


$$\vec{E}_{in} \cdot \vec{C}_{in} + \vec{E}_{out} \cdot \vec{C}_{out} = -\frac{d\Phi_B}{dt} = 0$$

$$\overline{E_{out}} = \frac{E_{in} C_{in}}{C_{out}} \neq 0$$

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°. 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**.



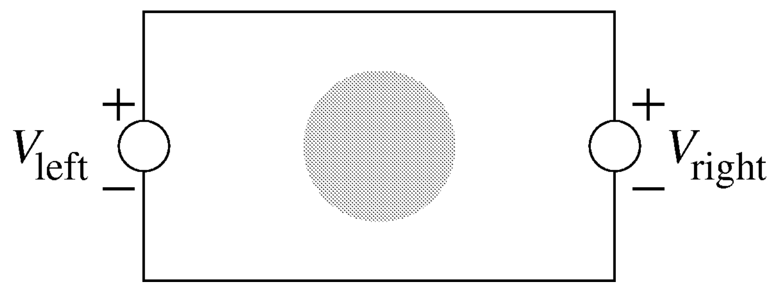
$$B = \frac{\mu_0 I}{2\pi d} / 2 = \frac{\mu_0 I}{4\pi d}$$

Problem 6 (15 points)

Two voltmeters, V_{right} and V_{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_{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_{left}?



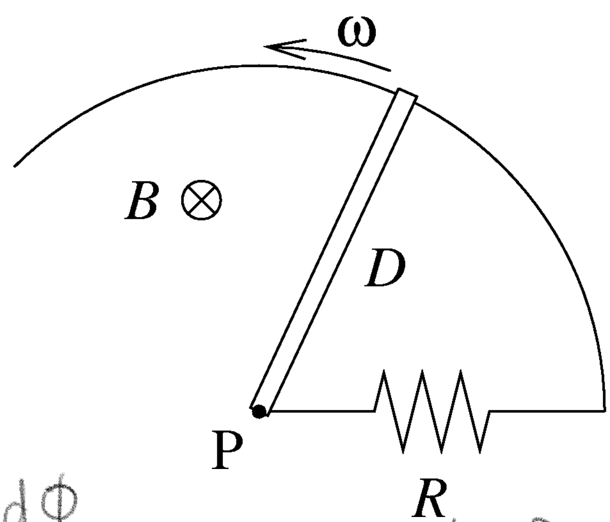
EMF = 0.2 V

V left = 0.1 V

Problem 7 (16 points)

A conducting bar of length D rotates with angular frequency ω 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, ω, R, and B.



$$\text{EMF} = -\frac{d\Phi}{dt} = \omega \cdot D \cdot D \cdot \frac{1}{2} \cdot B$$

$$I = \frac{\omega B D^2}{2R}$$