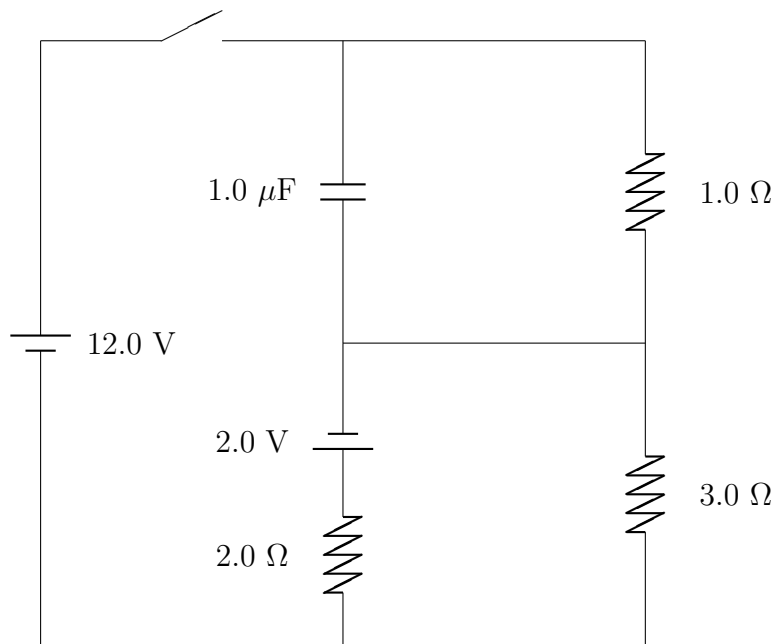


Feel free to ask me questions, including whether you've correctly solved any given problem.

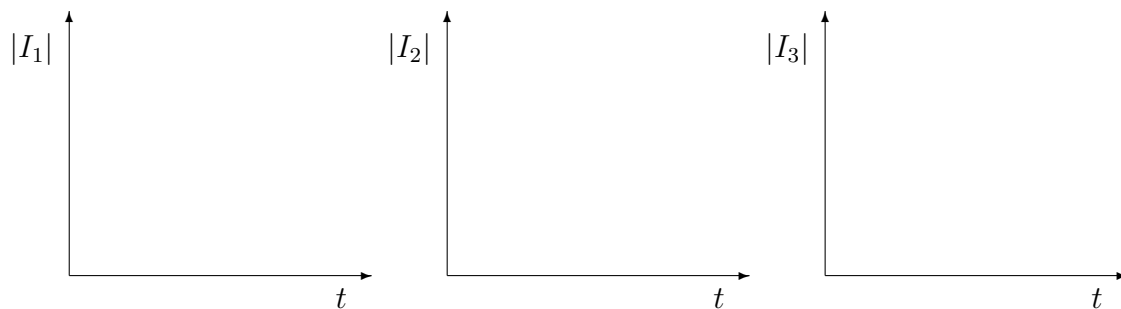
1. (70 points) Just before the switch is closed, the capacitor in the following circuit is completely discharged. You then close the switch.



- (a) Find the currents through all the resistors *immediately after* the switch is closed, before the capacitor has any time to charge up at all.

- (b) Find the currents through all the resistors *a very long time after* the switch is closed, after the capacitor has completely charged up.

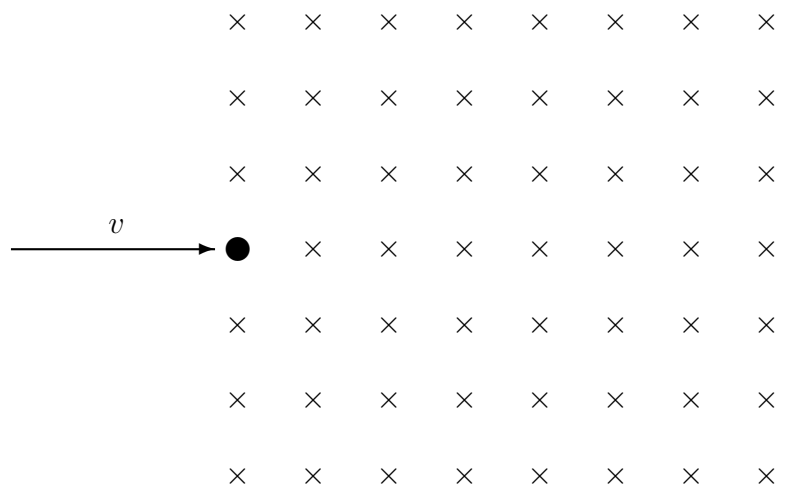
- (c) Sketch qualitative I vs t graphs for each of the currents. The switch closes at $t = 0$.



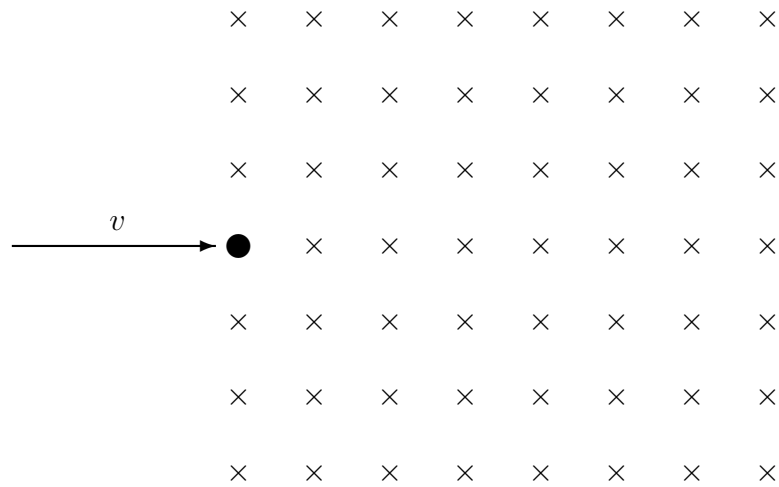
2. (50 points) This question is about charges in electric and magnetic fields.

(a) Magnetic fields act on moving charges. To get electrons moving at high speed, we can accelerate them by using a high voltage. Say an electron with charge $-e$ and mass m starts at rest, and gains kinetic energy by accelerating through a voltage difference of $-V_a$. What is v , its final speed, in terms of e , m , and V_a ?

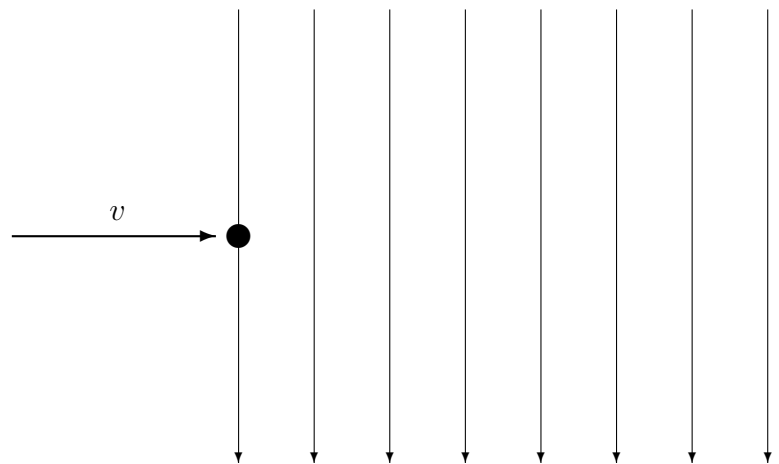
(b) An electron with speed v , moving toward the right, enters a region with a uniform magnetic field with magnitude B . The magnetic field points into the page. What is the magnitude of the magnetic force on the electron, F_B , in terms of B , e , m , and V_a ? Draw its direction as the rightward-moving electron just enters the region with the uniform magnetic field into the page.



- (c) Draw a diagram showing the *trajectory* of the electron in the same magnetic field. (The black dot is, once again, the electron entering the magnetic field.)



- (d) Now say that the electron, instead of emerging into a magnetic field, enters a region with a uniform electric field. The electron with speed v , moving toward the right, comes in between the plates of a parallel plate capacitor that produces an electric field with magnitude E . The field points downward on your page. Draw a diagram showing the trajectory of the electron in the uniform electric field.



- (e) The capacitor has a voltage difference of V_c across its plates, which are separated by a distance d . What is E , the magnitude of the electric field in this capacitor, in terms of V_c and d ?
- (f) Now say that the electron with speed v emerges into an region where *both* a uniform magnetic field and a uniform electric field exists in the ways described in (b) and (d). If the magnitude B is just right, the electric force and magnetic force will cancel each other out and the electron will not be affected. Find this value of B in terms of V_c , V_a , e , m , and d .

3. (40 points) You run into someone selling a “special antimagnetic covering” for your phone, claiming that it is at risk from “fluctuations in the Earth’s magnetic field.” In fact, they say, the Earth’s magnetic field may flip direction any day now, and you’ll end up with magnetic North changing to magnetic South in the space of an hour. When that happens, your phone circuits will be disrupted and destroyed, and so you need protection.

You know no such thing is about to happen, but just in case, do a quick calculation to estimate whether it might be worth buying protection from a magnetic field flip. You can find any numbers you need in your textbook, or make up what you think are reasonable numbers for your phone or anything else you need.

4. (40 points) An important discovery in the 1980s was the W^+ and W^- , which are among the particles responsible for the weak nuclear force. W^+ and W^- are antiparticles of each other, and they each have a rest mass of $80.4 \text{ GeV}/c^2$. Say you want to create a W^+ and W^- pair by a head-on collision of an electron and a positron (e^- and e^+) into each other at speeds close to the speed of light. The rest mass of an electron (and a positron, its antiparticle) is $0.511 \text{ MeV}/c^2$. (Remember: $1 \text{ GeV} = 1000 \text{ MeV}$.)

- (a) As observed from the lab frame of reference, the e^- and e^+ head toward each other with equal and opposite velocities in the collision. What is the minimum time dilation factor γ that the e^- and e^+ must have in order to produce enough energy to create a W^+ and W^- pair at rest?

(b) Say that in the lab frame of reference, the electron traveled 30.0 km at a constant speed corresponding to the γ you calculated in (a). How far did it travel in its own frame of reference?

(c) Calculate how long it took for the electron to travel 30.0 km in the lab frame of reference. Then calculate how long this time interval was in the electrons own frame of reference.